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Environmental Context in Child Behavioural Difficulties: Exploring the role of Executive Function (EF) and Emotion Regulation (ER)

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Environmental Context in Child Behavioural Difficulties:

Exploring the role of Executive Function (EF) and Emotion Regulation (ER).

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Abstract

Executive Function (EF) deficits are evidenced in children with behavioural difficulties. Yet, it is not clear how specific executive processes impact maladaptive behaviour in this population. What is more, previous research suggests that not only are EF and emotion regulation (ER) intrinsically linked to behaviour difficulties, but evidence also indicates that emotionally salient contexts have a negative impact on such processes which allow a person to control their behaviour. Therefore, efforts to examine how these control processes are impaired in different situations or contexts are presented in this thesis.

Understanding the structure of EF in typically developing children is an important first step in examining the relationship of executive dysfunction and behaviour difficulties in atypical child populations. Therefore, the first endeavour of this work addressed the unresolved EF structure during development at a neural level, through a meta-analysis of functional magnetic resonance imaging (fMRI) data of 1,177 typically developing children across 53 studies. Results indicated a structural model with both common and distinctive EF processes, as found in adults, can be applied to children. However, separable updating and switching processes were more apparent when adolescents were considered alongside children, suggesting distinction of these specific executive processes may occur later in development. A secondary meta-analysis, utilising the same data followed, which examined activation pertaining to task-specific components of EF engagement. Results show executive tests involving visual letter stimuli (when compared to arrow, pictorial or spatial stimuli) recruited a particularly large proportion of common EF, and updating activation maps. Further, through assessing their contribution at a neural level to common EF, it was possible

to rank inhibition tests. These findings not only contributed to the task-impurity problem but informed the development of a new online EF battery, which was subsequently administered to children in the main empirical study presented in chapter 5.

The work presented in chapters 4 and 5 investigated emotionally salient contexts which elicit clinically relevant behaviours, and the effect these contexts have on EF and ER, in 63 children across the diagnostic spectrum who presented with internalising and externalising behaviour. Parental interview data regarding contexts that most negatively impact their child's behaviour revealed two clinically meaningful groups, that is- children who were more negatively affected by situations which threaten their self-concept, and children who were more negatively affected by situations which do not threaten their self-concept. Logistic regression analyses were carried out to examine if specific EF and ER profiles predict membership into our contextually specified groups. Results indicated significant interactions between EF (at multiple levels) and maladaptive ER in predicting context group classification. However, no corresponding significant results pertaining to membership of diagnostic groups were found, suggesting that contextual factors and the impact they have on control processes, may be more important than diagnostic status, when considering behavioural change. Importantly, findings also demonstrate that updating deficits contribute to impairment in contexts which support a negative self-concept, which further exacerbate engagement in self-focused maladaptive ER. Therefore, further consideration of the role updating plays in self-focused ER and in turn, behaviour difficulties in children, is needed, which may inform important tailored intervention work for this population.

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Statement of Contribution

The work presented in this thesis was designed by Róisín McKenna, who also led the conduct of all studies reported. A number of QUB masters students and volunteers assisted in some data collection for chapters 4 and 5 — this contribution was coordinated by Róisín, who collected the vast majority of the data. Chapter 3 is part of a wider study on the development of an EF battery. Róisín's contribution was the conduct of the meta-analysis reported, which informed specified developments to the battery.

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Chapter 1

An Introduction to Executive Function (EF) and Atypical Child Development

1.1 Introduction

Executive Function (EF) refers to a family of top-down cognitive processes which are recruited to carry out effortful mental skills and behaviour directed at a goal, such as paying attention, quickly adapting your responses to a changing environment, or exhibiting the ability to stop your actions when needed. EF skills are essential for healthy physical, cognitive, social and psychological development (Diamond, 2013). Research indicates better EF is associated with enhanced academic performance (Gerst, Cirino, Fletcher, & Yoshida, 2017; Gropen, Clark-Chiarelli, Hoisington, & Ehrlich, 2011) greater physical health outcomes (Shields, Moons, & Slavich, 2017; Suchy et al., 2016), less risky behaviours (Walshe, McIntosh, Romer, & Winston, 2017), increased social skills (Hensler et al., 2014), and better employment outcomes (Tomaszewski, Fidler, Talapatra, & Riley, 2018). On the other hand, impairment in EF has been extensively linked to behavioural problems (Karasinski, 2015; Woltering, Lishak, Hodgson, Granic, & Zelazo, 2015). And is evidenced in individuals with several mental disorders, perhaps most notably neurodevelopmental disorders (Booth, Charlton, Hughes, & Happe, 2003; Kenworthy, Yerys, Anthony, & Wallace, 2008; Woodcock, Oliver, & Humphreys, 2009).

This relationship between EF and behaviour is the core subject of this thesis. A particular focus pertains to how the relationship is expressed in children with and without developmental diagnoses, and the situations which enforce demands on such executive processing and in turn, elicit maladaptive behaviour responses. The remainder of this chapter will briefly discuss theories regarding the structure of EF and how EF develops in childhood. Further commentary considers impairment in EF in neurodevelopmental disorders, as well as the “transdiagnostic” approach to examining the expression of such processes across psychiatric classifications.

1.2 Structural Models of EF

1.2.1 The Unitary View of EF

Over the past few decades, there has been much debate on the structure of EF, with the focus centring around two main proposals. The first considers EF as a unitary entity. Some influential models of this nature have arisen from work on memory and attention systems, which describe how such systems are controlled. For example, Baddeley’s working memory model describes three components: the central executive and its two ‘slave’ systems, the phonological loop and the visuospatial sketchpad (Baddeley, 1992). The central executive is the main structure which attends to the regulation and control of cognitive processes, whilst delegating constituent responsibilities to the slave systems, specifically the upkeep of speech-related phonological and visuospatial information. In other words, the central executive acts as the executive function operator, with assistance from the two serving structures. Another theory which complements Baddeley’s model is that of Norman and Shallice’s Supervisory Attentional System (SAS), which proposes that an overriding attentional control system is needed to perform a complex or novel task (Norman & Shallice, 1986).

1.2.2 The Dissociative View of EF

The second principal approach - the dissociative view - argues that distinct executive processes are separable. Three of the most commonly examined executive processes are: withholding a dominant or highly practiced response (“inhibition”), the regular monitoring and revising of working memory content (“updating”), and changing flexibly between tasks and mental sets (“switching”) (Nee et al., 2013). Some executive tests, such as working memory span tasks, measure working memory capacity, which is the passive storage of information in short-term memory (Miyake et al., 2000). Working memory updating tasks are believed to directly measure over-arching executive processing, as a result of its controlling and manipulating role in information processing (Lehto, 1996). Support for this model emerged from clinical studies which indicated that different measures of EF could be performed by patients with varying degrees of competence, resulting in failure on one task but relative proficiency in another (Lawson et al., 2015; Shallice, 1988; Walsh et al., 2015).

This conflicting constellation of ability suggests that individual executive processes may be differentially vulnerable to impairment and/or amenable to improvement. Individual differences research, which utilised structural equation modelling techniques in a range of different populations, has provided further support for this view (Carvalho, Ready, Malloy, & Grace, 2013; Catale, Meulemans, & Thorell, 2015; Hull, Martin, Beier, Lane, & Hamilton, 2008; Testa, Bennett, & Ponsford, 2012; van der Sluis, de Jong, & van der Leij, 2007). Additionally, the dissociative view is also supported by evidence suggesting that different executive processes progress through different developmental trajectories (Diamond, 2001, 2002, 2006).

1.2.3 The Integrative Model of EF

Substantial evidence supporting both of the aforementioned theories of EF structure led Miyake and colleagues to propose an integrative model (Miyake et al., 2000). This model consolidates both the unitary and dissociative facets of the previous proposals, as it promotes a common EF system with partially separable processes consistent with those discussed in the dissociative theory (Miyake & Friedman, 2012), a suggestion first presented by Teuber (1972). As this model provides the basis for the meta-analytic examination on the structure of EF in development presented in chapter 2, and indeed subsequent work presented in the thesis, more detail on the integrative model will be discussed in chapter 2.

1.3 The Development of EF

In light of the increased interest in componential aspects of EF development, research assessing the emergence and maturation of specific executive processes has ensued. Generally, a hierarchical, progressive outlook of development in the three commonly examined EF domains mentioned is accepted. However, due to the abundant basic pre-requisite skills needed to acquire executive functions (e.g. selective attention), EF development is not a linear process (Garon, Bryson, & Smith, 2008b). Literature relevant to the development of inhibition, updating and switching will now be considered.

1.3.1 The Development of Inhibition

Work by Garon et al. (2008) advocates that simple inhibitory control emerges between 6 and 12 months old, as this is when the ability to delay responses and override conflict between primary and secondary responses becomes apparent. Complex inhibition, that is the combination of both inhibition and holding representations or rules in working memory, develops by the age of 2 years old (Garon et al., 2008b). Some argue development in inhibition performance ceases in late childhood (Romine & Reynolds, 2005), Indeed, Welsh, Pennington and Groisser (1991) argued maturity is acquired at 10 years. This is supported by longitudinal fMRI results examining target detection performance at 9 and 11 years, which suggests that inhibition maturity occurs in late childhood (Durston et al., 2006). These authors found that brain activation changes from diffused patterns at 9 years to increased localisation at 11 years, when correlations with task performance were observed, indicating a developmental shift in inhibitory control. Whereas, Levin et al. (1991) proposed adult levels of inhibitory control are reached at 12 years old. However, in contrast, others have found evidence of inhibitory maturation through adolescence and even adulthood (Huizinga, Dolan, & van der Molen, 2006; Leon-Carrion, García-Orza, & Pérez-Santamaría, 2004). Therefore, it is clear there is evidence of inhibition processes reaching maturity throughout childhood and adolescence. Perhaps these conflicting reports can be explained by the task paradigms used across studies to index inhibition. Nevertheless, further work to clarify this trajectory, which also considers the specific demands of differential tools used to measure inhibition, is needed.

1.3.2 The Development of Updating

Research identifies working memory capacity as the first pre-requisite to EF to emerge, as holding basic representations in memory tend to initiate before 6 months (Pelphrey et al., 2004). Reznick, Morrow, Goldman and Snyder (2004) found that during a delayed-response task, infants exhibited appreciable working memory abilities by the middle of their sixth month. Additionally, the employment of chunking strategies has even been established in infants aged 7 months old (Moher, Tuerk, & Feigenson, 2012). Garon et al. (2008) argue that the onset of complex working memory capabilities, such as updating, does not occur until 15 months old, however, successive updating of object representations have been found in infants as young as 11 months (Moher & Feigenson, 2013). Working memory attainment (encompassing both WM capacity and WM updating) follows a linear trajectory in early childhood and subtle adjustments taking place during adolescence and early adulthood (Gathercole, Pickering, Ambridge, & Wearing, 2004; Satterthwaite et al., 2013). fMRI findings support these developmental transitions, as age-related brain activation changes have been observed in individuals aged 7-20 years during visuospatial working memory updating performance (Kwon, Reiss, & Menon, 2002).

1.3.3 The Development of Switching

Switching has been described as a more sophisticated executive process than those aforementioned, as its development relies on the acquisition of both inhibition and working memory e.g. in order to switch between mental sets, rule representations need to be retained in working memory and inhibition of engagement with previous sets needs to be implemented (Best, Miller, & Jones, 2009; Garon et al., 2008b).

Switching flexibly in a simple stimuli-response nature is acquired by the age of 1, however, attention switching, which requires a perceptual shift, can develop between approximately 2.5 and 4 years old, depending on the level of conflict involved. Levin et al. (1991) suggests that competence in mental flexibility can be achieved by the age of 12, however, Davidson, Amso, Anderson and Diamond (2006) reported that task flexibility, even with relatively low reliance on working memory, is not fully mature at 13 years. In their fMRI study, Morton, Bosma and Ansari (2009) investigated attention switching in children aged 11 and 13 years and adults aged 19 to 25 years. Changes in the location of neural activity associated with switching between the two groups were reported in the fronto-parietal regions and thalamus, despite comparable switching performance, suggesting that adult-like patterns of neural activity supporting switching may be evident by the age of 13.

Thus, from initial acquisition to full maturity, the development of specific EFs tends to follow a general stage-like progression. However, it also seems reasonable to suggest that each specific executive process may need to navigate through partially independent pathways at different rates during development, in order to progress to adult-levels of attainment.

1.4 EF Deficits in Developmental Disorders

EF impairment has been extensively evidenced in individuals with autism spectrum disorder (ASD) (Hill, 2004; Hughes, Russell, & Robbins, 1994) and has been linked with deficient theory of mind (Ozonoff, Pennington, & Rogers, 1991), as well as restricted, repetitive behaviours (Lopez, Lincoln, Ozonoff, & Lai, 2005) and social functioning impairments (Mac Mullen Freeman, Locke, Rotheram-Fuller, &

Mandell, 2017) in this population. Executive dysfunction at a neural level has been found in ASD samples, and has been argued to be attributable to disordered cortical connectivity in regions associated with EF (Han & Chan, 2017; Just, Cherkassky, Keller, Kana, & Minshew, 2007). EF deficits have been implicated in the expression of other developmental disorders, e.g. Attention Deficit Hyperactivity Disorder (ADHD) (Antshel et al., 2010; Barkley, 1997; Rabinovitz, O'Neill, Rajendran, & Halperin, 2016), Conduct Disorder (CD) (Toupin, Déry, Pauzé, Mercier, & Fortin, 2000), Tourette syndrome (Yaniv et al., 2018), Down syndrome (Amadó, Serrat, & Vallès-Majoral, 2016), as well as Klinefelter and Trisomy X syndromes (Lee et al., 2015).

1.4.1 Diagnostic Heterogeneity of EF Skills

While some research points toward specific profiles of deficit in EF within particular diagnostic groups, findings show substantial heterogeneity in EF ability within disorders (Fair, Bathula, Nikolas, & Nigg, 2012). This prompted Dajani and colleagues (2016) to examine whether EF presents heterogeneously in highly comorbid neurodevelopmental disorders, specifically, ASD and ADHD, as well as typically developing children (Dajani, Llabre, Nebel, Mostofsky, & Uddin, 2016). Results indicated that differences in EF performance (classed as 'above average', 'average' and 'impaired') could not delineate diagnostic groups, with 'average' and 'impaired' EF exhibited by children with ASD and children with ADHD. Thus, suggesting heterogeneous expression of EF within these diagnostic categories. Moreover, the researchers also reported greater EF impairment predicted more severe internalising and externalising problems, such as anxiety, depression and aggression. These findings suggest differences in EF may act as an important clinical indicator for assessing children across diagnostic boundaries. And perhaps, researchers should be more cautious of assuming homogeneity in EF ability in both clinical samples and control samples.

1.4.2 Comorbidity in Neurodevelopmental Disorders

Neurodevelopmental disorders are comorbid (Gabis, Baruch, Jokel, & Raz, 2011; Jeste et al., 2016; Lyall et al., 2017; Thapar & Cooper, 2016). Furthermore, psychiatric comorbidity in neurodevelopmental disorders and intellectual disabilities has been the source of much investigation (King, 2016). One highly prevalent presentation is ASD comorbid with anxiety disorders (van Steensel, Bögels, & Perrin, 2011). Indeed, Salazar et al. (2015) found that 66.5% of pre-school and school-aged children with ASD presented with generalised anxiety disorder and 52.7% showed symptoms of specific phobias, and 59.1% of ADHD symptoms. When anxiety presents in individuals with ASD, often the expressions of anxiety are complex, with multiple anxiety disorders exhibited (Rodgers & Ofield, 2018). Importantly, overlaps in symptoms between two disorders can prove to be a barrier to successful treatment, e.g. social anxiety in an individual with ASD can be easily mistaken to be a presentation of a social communication impairment- a feature of the classic ASD symptomatology (Zaboski & Storch, 2018). Additionally, children and adolescents with ASD may express atypical anxiety symptoms, not reflective of DSM categorisation, due to the interaction between the anxiety symptoms and ASD features (Morrow Kerns et al., 2014). Therefore, complex comorbidity may hamper clinical progress.

1.5 The Research Domain Criteria (RDoC) Framework

Co-occurring disorders and symptoms across, and heterogeneity within, diagnostic categories, as well as the lack of consistent findings in the biological aetiology for specific disorders, has encouraged the development of a new approach for assessing psychopathology. The Research Domain Criteria (RDoC) framework project was initiated by the National Institute of Mental Health (NIMH), and proposes a new nosology perspective for mental illnesses. The RDoC approach questions the validity of traditional diagnostic groups as categorised by current diagnostic systems, such as the Diagnostic and Statistical Manual of Mental Disorders (DSM) and the International Classification of Diseases (ICD). The initiative emerged due to the inapplicability of such diagnostic systems to evidence arising from research spanning genetics, neuroscience and behavioural sciences (Owen, 2014; Sanislow et al., 2010). The RDoC nosology aims to classify psychopathology on observable behaviours and identify neurobiological markers that reflect cognitive and behavioural dysfunction across traditional diagnostic groups. While it is not a diagnostic system intended to be used by clinicians in the near future, it is hoped that studying how these endophenotypes drive psychiatric presentation will provide better insight into the development of treatments aimed at improving the aberrant transdiagnostic processes or mechanisms identified (Cuthbert & Insel, 2013). RDoC proponents encourage putative transdiagnostic substrates to be examined across several units of analysis, including genes, molecules, cells, circuits, physiology, behaviour, and self-report (Morris & Cuthbert, 2012). And thus, stimulating research across various fields is paramount to the success of the approach. The nosology suggested by the RDoC project relies on three assumptions:1) mental illnesses are disorders of brain circuits, 2) clinical neuroscientific tools, such as functional neuroimaging and electrophysiology and in vivo connectivity methods can be used to recognise putative neural dysfunction, 3) bio-signatures can be identified by genetics and clinical neuroscience which can act as a liability to psychiatric symptoms (Insel et al., 2010).

Developmental researchers have called for the RDoC framework to be informed by, and adopted in future research efforts committed to elucidating child psychopathology in particular (Franklin, Jamieson, Glenn, & Nock, 2015; Garvey, Avenevoli, & Anderson, 2016). Indeed, DSM-defined classification criteria is especially constrained in the developmental period, due to strict age parameters for the diagnosis of some disorders. However, identifying early indicators of conditions could contribute to effective early intervention or even prevention in some cases (Franklin et al., 2015). Therefore, developmental pathology work could benefit substantially from employing a transdiagnostic approach.

1.5.1 EF as a Transdiagnostic Marker

A specific domain that has been classified as an indicator for pathology across the diagnostic spectrum is EF. Goodkind and colleagues (2015) conducted a meta-analysis of structural neuroimaging studies across 6 psychiatric conditions in order to identify neural transdiagnostic substrates (Goodkind et al., 2015). To follow up on the structural results of the meta-analytic investigation, the researchers also carried out 3 large-scale studies assessing associated functional connectivity of a healthy sample. Their findings showed gray matter loss in areas comprising interconnected networks responsible for EF processing across all diagnostic groups, thus providing a neurobiological basis for compromised EF across disorders. Transdiagnostic dimensional approaches to EF have also been applied to developmental samples.

Research has found EF to be associated with a general psychopathology factor in a large cohort adolescent sample aged between 11 and 19 years (Bloemen et al., 2018). In their study, psychopathology was divided into various domains indicative of ASD, ADHD, internalising and externalising symptomatology. While there were disorder-specific EF impairments found, this work suggests deficits in multiple EF processes index cross-diagnostic dysfunction in development. In addition, working memory capacity, which is highly related to executive ability, has also been reported to represent a transdiagnostic dimension across developmental diagnostic groups, and is specifically linked with externalising problems (Huang-Pollock, Shapiro, Galloway-Long, & Weigard, 2017).

1.5.2 Environmental context and transdiagnostic markers of dysfunction

In their model for augmenting transdiagnostic endeavours, Nolen-Hoeksema & Watkins (2011) integrate environmental contextual factors and emotional reactivity to stimuli in the environment, with intra-person markers (such as cognitive and emotional processing) for contributing to the expression of general psychopathology. Furthermore, it has been argued it is an absolute necessity when investigating general developmental psychopathology in particular, to consider contextual factors in addition to biosignatures, as illustrated by the RDoC perspective. Classification of pathology in the developmental period is shaped by contextual factors, i.e. normative behaviours in pre-school aged children can be perceived as behaviour suggestive of psychiatric dysfunction during adolescent years. Therefore, it could be argued in order to contribute to research committed to understanding developmental psychopathology across diagnoses, a consideration beyond biological substrates of transdiagnostic constructs, must be explored in the context of their interaction with the environment (Franklin et al., 2015). The use of functional groupings in child transdiagnostic research has been suggested as a way to consider situations in which such symptoms occur (Dirks, De Los Reyes, Briggs-Gowan, Cella, & Wakschlag, 2012) - a perspective this work adopts.

1.6 Thesis Overview

This work comprises six chapters in total. Chapter 2 presents a meta-analytic examination of the neural correlates of EF in typical children and adolescents, by assessing fMRI brain activation (McKenna, Rushe, & Woodcock, 2017). This meta-analysis aims to inform on the structure of EF in development, through assessing the applicability of the integrative model structure found in adults (Miyake et al., 2000). As such, the study explores common and distinct neural activation representative of EF, and in particular the three most commonly referenced executive processes, inhibition, switching and updating.

As it has been extensively reported, EF is notoriously difficult to measure in isolation, due to its reliance on lower-level cognitive processes, integral to the expression of executive processing. Therefore, EF measurements are prone to task-impurity issues and so, attempts to develop accurate EF assessment tools are paramount. In line with this, a second meta-analysis, again utilising the previous fMRI data of children and adolescents (used in chapter 2), was carried out to examine the effect of idiosyncratic non-executive task demands on EF neural activity. This work is outlined in chapter 3. Data was analysed at a stimulus-type level by investigating the effect of the modality of stimuli used across tasks on EF activity. And at a test-type level for inhibition tasks. In other words, ascertaining how different inhibition tasks contribute to executive activation across studies.

Chapter 4 and 5 are outputs relating to what we termed the IN CONTROL (Investigating Contexts That impact the Regulation Of Life) study. This study turns the focus to exploring emotionally salient situations or contexts which have the potential to place demands on processes that allow a person to control their behaviour. The control processes we refer to are EF and Emotion Regulation (ER) strategies, as previous research has reported a link between these processes and maladaptive behaviour. All children included in the research displayed clinically relevant behaviour difficulties, yet specific diagnostic criteria were not a requirement to participate. Thus, children across the diagnostic spectrum took part.

As demonstrated in chapter 4, descriptive data regarding the emotionally salient context identified by parents as the most negatively impacting revealed two meaningful themes, and as such, children were separated into two corresponding groups. The groups consisted of 1) children who were most affected by contexts that threaten their self-concept and 2) children who were most affected by contexts that do not threaten their self-concept. Qualitative data extracted from parental interviews which informed on these groupings are reported in this chapter.

Chapter 5 examines whether EF and ER predict membership into the contextually-specified groups and as such, whether distinct EF and ER profiles can explain contextual impairment. Logistic regression analyses were carried out. Analyses pertaining to internalising and externalising behaviour profiles, parenting styles and the emotional salience of contexts were also conducted.

Finally, Chapter 6 provides an overall discussion of the work of the thesis, which spans EF as a theoretical construct and as neural correlates, to the measurement of EF, its impact on behaviour and how it can be shaped by other processes (i.e. ER) and environmental demands. Implications of the research endeavours illustrated in the thesis are discussed, including their relevance to future clinical intervention work. Further, limitations of the general assumptions taken by the perspective presented in this work are considered.

As previously discussed, the subsequent chapter examines the structure of EF in children by investigating neural activation during executive tasks, as measured by functional magnetic resonance imaging (fMRI). The meta-analysis illustrated here is a previously published journal article (*in Frontiers in Human Neuroscience*) and while minor alterations have been made to complement the thesis format, it is largely presented as it was as the published work.

Chapter 2

Informing the structure of executive function in children: a meta-analysis of functional neuroimaging data[1]

2.1 Abstract

The structure of executive function (EF) has been the focus of much debate for decades. What is more, the complexity and diversity provided by the developmental period only adds to this contention. The development of executive function plays an integral part in the expression of children's behavioural, cognitive, social and emotional capabilities. Understanding how these processes are constructed during development allows for effective measurement of EF in this population. As the first study of its kind, this meta-analysis aims to contribute to a better understanding of the structure of executive function in children. A coordinate-based meta-analysis was conducted (using BrainMap GingerALE2.3), which incorporated studies administering functional magnetic resonance imaging (fMRI) during inhibition, switching and working memory updating tasks in typical children (aged 6-18 years). The neural activation common across all executive tasks was compared to that shared by tasks pertaining only to inhibition, switching or updating, which are commonly considered to be fundamental executive processes. Results support - for the first time at a neural level - the existence of partially separable but partially overlapping

[1] Chapter 2 is a published work. [McKenna, R., Rushe, T., & Woodcock, K. A. (2017). Informing the Structure of Executive Function in Children: A Meta-Analysis of Functional Neuroimaging Data. *Frontiers in Human Neuroscience, 11*, 154. doi: 10.3389/fnhum.2017.00154]

inhibition, switching and updating executive processes in children over 6 years. Further, the shared neural activation across all tasks (associated with a proposed "unitary" component of executive function) overlapped to different degrees with the activation associated with each individual executive process. These findings provide evidence to support the suggestion that one of the most influential structural models of executive functioning in adults can also be applied to children of this age, while calling for careful consideration and measurement of both specific executive processes, and unitary executive function in this population. However, they also highlight the need for a new systematic developmental model, which captures the integrative nature of executive function in children.

2.2 Introduction

Executive function (EF) is an umbrella term for a number of inter-related cognitive processes needed for purposeful, goal-orientated behaviour (Anderson, 2001; Lerner & Lonigan, 2014). EF enables the regulation and monitoring of high level cognitive resources and is usually employed in novel situations (Burgess & Stuss, 2017; Shallice, 1988; Stuss, 1992). Cognitive processes associated with EF include planning, problem-solving, novel thinking, and the ability to adapt behaviour to the changing environment (Banich, 2004; Zelazo, Muller, Frye, & Marcovitch, 2003). Additionally, EF performance has been shown to reliably predict many intellectual and social competencies, such as school readiness (Welsh, Nix, Blair, Bierman, & Nelson, 2010), early literacy and numeracy attainment (Blair & Razza, 2007), later school accomplishment (Checa & Rueda, 2011) and social understanding (Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006). In this paper, the terms ‘executive function’ and ‘cognitive control’ will be used interchangeably to reflect the divided terminology used in current literature.

Broadly speaking, impairment in EF has been linked to behavioural problems, and is evidenced in individuals with neurodevelopmental disorders including reading disorders, attention deficit hyperactivity disorder (ADHD), autism and several genetic syndromes, including for example, Prader-Willi syndrome (Booth et al., 2003; Danforth, Connor, & Doerfler, 2016; Kenworthy et al., 2008; Visser, Berger, Van Schrojenstein Lantman-De Valk, Prins, & Teunisse, 2015; Woodcock, Humphreys, Oliver, & Hansen, 2010; Woodcock, Oliver & Humphreys, 2009). Despite this, findings in relation to how EF may be linked to clinically relevant behaviour remain largely inconsistent. The focus of the present meta-analysis is to investigate the neural structure of EF in children since precise understanding of the structure of EF during typical development is a necessary first step in elucidating the executive underpinnings of clinically relevant behaviour in individuals with neurodevelopmental disorders.

2.2.1 The Structure of EF

There has been much debate on how executive function is structured, for example on how far individual executive processes that make regular appearances in the literature may reflect manifestations of a single EF capacity or of multiple component processes (Best et al., 2009; Miyake et al., 2000). However, a leading theory, known as the integrative model (Miyake et al., 2000), consolidates such unitary and dissociative views. In line with processes very commonly discussed in the literature on the typical and atypical development of EF, and its role in behaviour (Blair, 2016; Friedman, Miyake, Robinson, & Hewitt, 2011; Harvey et al., 2004; Karasinski, 2015; Roelofs et al., 2015), the three executive processes considered in most work taking an integrative perspective are: withholding a dominant or highly practiced response (“inhibition”(inhibit)), the regular monitoring and revising of working memory content (“updating” (update)), and changing flexibly between tasks and mental sets (“switching”(switch)) (Nee et al., 2013). The most recent incarnation of the integrative model identifies an underlying commonality (“common executive”) – assumed to contribute to all executive processes and, it has been argued, to be virtually indistinguishable from inhibition – alongside separable switching and updating processes, which rely on common EF and corresponding unique components (Friedman et al., 2008; 2011; Miyake & Friedman, 2012).

Critically then, there is a currently open question about which executive processes can be viewed as truly separable, and exactly how these are related to each other. This question is fundamentally important for understanding the nature of executive dysfunction in atypically developing populations and its relationship to behaviour. For example, it has been argued that switching specific demands, which require flexibility, lie in opposition to goal maintenance in the face of distractions, which are demands that have been attributed to common executive (Blackwell, Chatham, Wiseheart, & Munakata, 2014; Dreisbach & Goschke, 2004; Goschke, 2000). Indeed, individual differences in different executive processes have been associated but in opposite directions, with attention problems and self-regulatory behaviours (Friedman et al., 2007, 2011b; Young et al., 2009). Yet much work on atypically developing populations has tended to take a perspective driven by the measures available – with relatively little attention to underlying structure – which has often not allowed measure-related and process-related effects to be clearly distinguished (Van Eylen et al., 2011). Better understanding of how EF processes can be separated is thus required to drive productive research on how these processes can be impaired and the effects of such impairment. One way to further understanding in this regard is with examination of neural constituents of EF.

2.2.2 The neural picture of EF

Since its initial description, the integrative EF model has been applied to child samples in several studies using test performance related indicators of EF (Agostino, Johnson, & Pascual-Leone, 2010; Davidson et al., 2006; Hughes, 1998; Pe, Raes, & Kuppens, 2013; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Rose, Feldman, & Jankowski, 2011). Early results from both exploratory and confirmatory factor analyses demonstrated that, as in adults, there are three inter-related executive processes in children aged 8-13 years (Lehto et al., 2003). However, subsequent studies have not always been consistent in that switching and updating have not always been distinguishable in children (Huizinga et al., 2006; Miller, Giesbrecht, Müller, McInerney, & Kerns, 2012; St Clair-Thompson & Gathercole, 2006; Usai, Viterbori, Traverso, & De Franchis, 2014; van der Sluis et al., 2007; Wiebe et al., 2011). Thus, even applying closely equivalent approaches, the question of how applicable the integrative model is to the developing brain remains to be resolved. It is important to note that these studies have applied a range of different measures to examine EF in children, which could contribute to the inconsistent findings. A neural functional approach that includes multiple measurement approaches can therefore, further our understanding of the discriminability of executive processes in children.

In adults, attempts to examine the structure of EF in a neural context have generally provided support for the integrative model. For example, application of a computational neural network model has provided support for common EF and switching specific components of a switching process (Herd et al., 2014). Further, meta-analyses of fMRI data have allowed patterns of activation to be discriminated across putatively separable executive processes (Lenartowicz, Kalar, Congdon, & Poldrack, 2010), but have still identified common activation indicative of an overarching cognitive control network (Niendam et al., 2012). However, even in adults, attempts to examine the neural constituents of multiple executive processes in the same meta-analysis (Buchsbaum, Greer, Chang, & Berman, 2005; Derrfuss, Brass, Neumann, & Von Cramon, 2005) have been limited by use of a single task to tap each process, making it impossible to distinguish between EF process-related and EF task-related findings (Nee et al., 2013).

In children on the other hand, neuroimaging work has generally focused on the emergence and maturation of specific executive processes in children. The development of inhibition, switching and updating (in the broader context of WM) has been examined separately (Durston et al., 2006; Kharitonova, Winter, & Sheridan, 2015; Kwon et al., 2002; Morton et al., 2009; Murphy, Foxe, & Molholm, 2016; Satterthwaite et al., 2013) and when assessed collectively, the evidence suggests that from an integrative model perspective, we might expect common executive, switching and updating to show distinguishable developmental trajectories. Indeed, previous fMRI examinations have found age-related activation changes, pertaining to inhibition, switching and updating respectively, during childhood and adolescence, indicating that these executive processes undergo distinct developmental transitions (Durston et al., 2006; Kwon et al., 2002; Morton et al., 2009).

2.2.3 Meta-analytic investigations

There is a clear lack of meta-analytic investigation using neuroimaging data pertinent to EF in typical children. Many such analyses have incorporated both children and adults in a single sample and have tended to focus on clinical evaluation, particularly those relevant to ADHD (Cortese et al., 2012; Dickstein, Bannon, Castellanos, & Milham, 2006; Hart, Radua, Nakao, Mataix-Cols, & Rubia, 2013). In addition, existing adult and/or child fMRI meta-analyses have tended to take a process specific or task specific approach rather than attempting to address how multiple executive processes are related to one another (e.g. Criaud & Boulinguez, 2013). Whole brain analyses also need to be utilized, as much of the literature considers a region of interest approach e.g. the insula (Chang, Yarkoni, Khaw, & Sanfey, 2013), or right ventrolateral prefrontal cortex (Levy & Wagner, 2011). Only one meta-analytic study, conducted by Houdé et al. (2010), has reviewed the 3 executive processes considered in the integrative EF model and of interest to the present study, using fMRI data from typical child and adolescent (aged 4-17 years, using an age cut-off of 11.4 years, as this was the midpoint) (Houdé, Rossi, Lubin, & Joliot, 2010). Houdé et al. found the regions of activation similar to those reported in adult samples. Yet, the authors only examined 'collective' activity pertaining to inhibition, updating and switching (which from an integrative model perspective could be viewed as common EF), but did not assess activation specific to individual executive processes. Thus, the findings cannot inform on the potential applicability of the integrative EF model to children or the relative commonality versus dissociation of individual processes.

2.2.4 The present study

The present study investigates the structure of executive function (EF) in children and adolescents, through examining fMRI activation during EF task performance. The executive processes of interest include inhibition, updating and switching, as emphasized by Miyake's integrative model. Further, an additional variable representing the unitary executive process ("common executive"), which includes the amalgamation of the three executive processes of interest, has been considered. Neural activation was investigated through the use of the BrainMap GingerALE software (version 2.3). In line with Miyake and Friedman's integrative model and the hierarchical model of EF development proposed by Garon et al. (2008), we hypothesize that activity relating to inhibition and common executive will largely indicate shared activation, which would provide support for inhibition and common executive processes being indistinguishable at a neural level. On the other hand, we hypothesize that significant non-shared activation will become apparent when common executive is compared to switching and updating, indicating the presence of switching-specific and updating-specific components of EF in children.

2.3 Method

2.3.1 Design

Papers relating to inhibition, switching and updating were identified. Following this, Activation-Likelihood Estimation (ALE) maps were produced to examine the location of brain activation during inhibition, switching and updating task engagement in the whole sample group (aged 6-18 years), and similarly to the study by Houdé et al. (2010), in studies comprising only children (6-12 years "child" group). Separate maps for each of the executive processes were created and a "common executive" map comprised shared activation across tasks tapping the individual executive processes. These maps were compared in terms of areas of significant overlap and areas of significant differentiation to examine neural integration versus distinction of the EF processes.

2.3.2 Study Selection

Literature searches were conducted in Web of Science, PubMed and PsycINFO between the dates of 23rd October 2014 and 24th April 2015. Keyword searches comprised the following terms combined with AND operators: 1. 'fMRI OR "functional magnetic resonance imaging", 2. child*, 3. inhibition OR Stroop OR "flanker task" OR switching OR updating etc. A full list of the terms used is reported in Table 1. Multiple variations of terminology were used for each executive process of interest. Where specific EF tasks with commonly used names were identified, these names were added to the search criteria such that for example, a study employing a Stroop task did not have to include the key word "inhibition" to be highlighted in the search. Notably, more such specific tasks were identified for inhibition (see Table 1). Some tests sometimes labelled as EF tests – such as WM span tasks – measure WM capacity, which we and others consider to be the passive storage of information in short-term memory, a different construct to WM updating (Chein, Moore, & Conway, 2011; Lehto, 1996; Miyake et al., 2000). Such tests were therefore excluded from the present meta-analysis.

Table 1. Lists of terms used in database searches

Search Terms	
fmri OR "functional magnetic resonance imaging" AND child* AND…..	**Inhibition** Go-No/Go Stroop Anti-saccade Simon Flanker "Stop Task" Stop-signal "Inhibition of an orientating response"
	Switching Shifting Cognitive flexibility Flexibility "Task switching" "Set shifting" "Task shifting" "Set switching"
	Updating "Working memory updating" "n back"

Initial inclusion criteria were typically developing child participants (aged 6 – 18 years) engaging with an inhibition, switching or updating task during fMRI acquisition. Consequently, 195 papers were retrieved from these searches. Typical development was defined as having had no prior diagnosis of a psychological problem, Thus, children could be deemed typically developing despite their suggested risk of a psychiatric disorder based on for example, expression of a genetic polymorphism variant or score on a clinical scale using “at risk” cut-offs (e.g. Mechelli, Viding, Pettersson-Yeo, Tognin, & McGuire, 2009; Van’t Ent et al., 2009). Following this, authors who did not report activations in standard stereotactic coordinate space (Talairach or Montreal Neurological Institute) were contacted and asked to forward coordinate activations if they had them, thus, unpublished data were included in the analysis. If the authors did not respond by 30th April 2015 or could not retrieve the coordinate data, their paper was excluded. Authors were also approached if only between groups (higher-level) comparisons were reported, or if activations isolating the executive process(es) of interest were not addressed, i.e. they had to report a contrast between an executive demand condition and a matched comparison condition that did not apply the executive demand. Further, if papers only provided activation data recorded during the pre-or post-stimuli intervals or if the contrasts were indicative of successful versus failed responses and vice versa. Again, if this communication did not result in the retrieval of the relevant data, the studies were excluded. Once these parameters were applied, 90 papers remained. Region-of-interest (ROI) analyses were excluded to prevent an activation bias (Kriegeskorte, Simmons, Bellgowan, & Baker, 2009; Poldrack, 2007). Some papers incorporated multiple experiments, either within or across the 3 executive processes. However, if it was not clear from the information available in the paper, further contact with the authors was made to ensure that data from one group of participants during an EF task reported in multiple papers or at multiple time points, was not duplicated. On the other hand, if the same participants completed more than one EF task, the data from these tasks was included and treated as separate data-sets in the analyses. It was ascertained that using data from the same participants across maps was appropriate when executive demands differed through the engagement of different EF tasks. Consequently, 49 papers endured, but with 53 experiments (Figure 1). Of these studies, 6 included 8 datasets, which have never been published before. Further to the database search, the reference lists from all applicable papers were also examined to identify potential additions to the meta-analysis, however, this resulted in no additional papers.

The final dataset included 1,177 participants with a mean sample age more than 6 years and less than 18 years (Table 2) — the whole sample dataset incorporated 573 activation foci. The child group incorporated 549 participants across 29 experiments, containing 317 activation foci. The cut-off for the child group was based on previous research indicating that executive processes tend to be relatively mature by the age of 12, yet not "fully established" (e.g. (Anderson, 2002). A demographic summary of each study including study name, participant age, number of participants, EF task used, stimuli, contrast and number of foci, is outlined in Table 2.

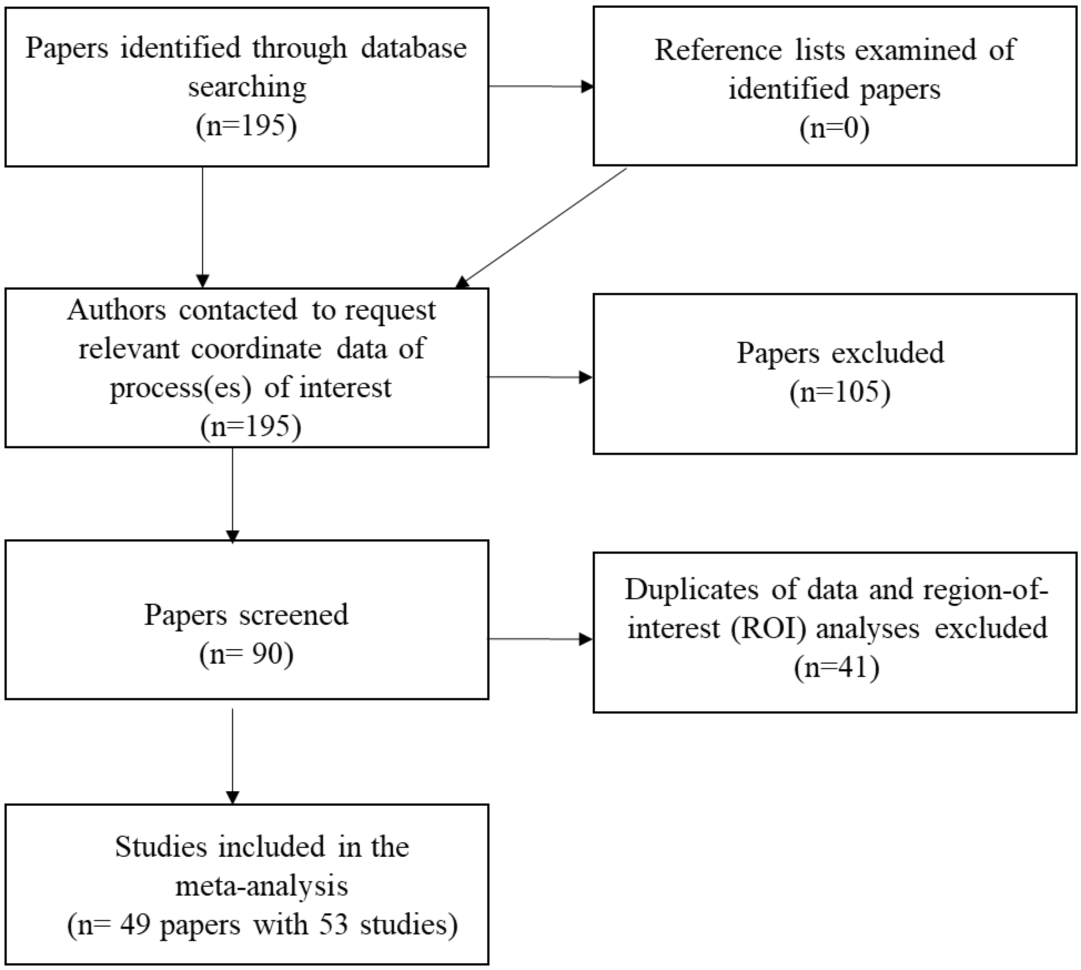

Figure 1. PRISMA flow diagram for study selection.

Table 2. List of studies included in the meta-analysis. Main study demographics are outlined: EF task administered, mean age (in years), sample size (n), the fMRI contrasts of interest and the number of foci of significant activation associated with the contrast.

	Study	Task	Mean Age(sd) r	n	Contrast	Foci
INHIBITION	Anderson, Schweinsburg, Paulus, Brown, & Tapert (2005)	Shape GNG	13.63(.88)	46	no-go > go	2
	Bennett et al. (2009)	Letter GNG	12	11	no-go > go	8
	Bhaijiwala, Chevrier, & Schachar (2014)	Letter Stop task	15.4(1.7) r=8-19	12	stop > go	4
	Christakou et al. (2009)	Simon task	r=10-17	36	incongru>congru	3
	Cubillo et al. (2014a)	Arrow Stop task	13.9(1.7) r=10-17	29	stop > go	9
	De Kieviet et al. (2014)	Flanker task	8.7(0.5)	47	incongru> congru/ neutral	2
	Durston et al. (2003)	Picture GNG	8.68(1.51)	7	no-go > go	8
	Fan, Gau, & Chou (2014)	Number Stroop	11.2(2.9)	23	incongru> congru	1
	Fitzgerald et al. (2008)	Shape A-S	11.5(1.8) r=8-14	11	Anti-correct vs pro-correct	12

	Halari et al. (2009)	Simon task	16.3(1.1)	21	incongru> congru	6
	Heitzeg et al. (2014)	Letter GNG	10.9(1.1) r=9.4-12.9 (baseline)	19	no-go > go	6
	Iannaccone et al. (2015)	Arrow non-spatial GNG	14.82(1.24) r=12-16	18	no-go > go	17
	Lei et al. (2012)	Letter GNG	11.5(1.9)	22	no-go > go	14
	Liu, Bai, & Zhang (2008)	Colour Stroop	14.3(3.3)	10	incongru> congru	18
	Mechelli et al. (2009)	Picture GNG	11.32(.67)	102	no-go > go	8
	Nosarti et al. (2006)	Arrow non-spatial GNG	17.2(1.1)	14	no-go - odd trials	10
	Posner et al. (2011)	Number Stroop	13.4(1.2)	15	number blocks vs neutral blocks	5
	Querne et al. (2008)	Letter GNG	10(1.1) r=8.2-11.6	10	no-go > go	14
	Rodehacke et al. (2014)	Simon task	14.6(.3) r=13.7-15.5	185	incongru> congru	14
	Rubia et al. (2006)	Simon task	15 r=10-17	29	incongru> congru	5
	Sheinkopf et al. (2009)	Picture GNG	r=8-9	12	no-go > go	4
	Sheridan, Kharitonova, Martin,	Simon task	8.1(1.66) r= 5.7–10.7	33	incongru> congru	7

	Chatterjee, & Gabrieli (2014)					
	Simmonds et al. (2007)	Picture GNG	10.6(1.5) r=8-12	30	no-go > go	10
	Singh et al. (2010)	Letter GNG	14.3(2.33)	22	no-go > go	2
	Siniatchkin et al. (2012)	Picture GNG	9.1(4.1) r=7-13	14	no-go > go	12
	Suskauer et al. (2008)	Picture GNG	10.8(1.3)	25	no-go > go	7
	Tamm, Menon, Ringel, & Reiss (2004)	Letter GNG	15.58(0.79) r=14–16	12	no-go > go (a vs b)	3
	Vaidya et al. (2005)	Flanker task	9.2(1.3)	10	incongru> neutral	4
	Van't Ent et al. (2009)	Colour Stroop	15.17(1.45)	18	incongru> congru	19
	Van't Ent et al. (2009)	Flanker task	15.17(1.45)	18	incongru> congru	20
	Ware et al. (2015)	Letter Stop task	15.09(1.51) r=13-16	21	stop > baseline (all stop coords)	7
SWITCHING	Christakou et al. (2009)	Spatial switching	r=10-17	36	switch > repeat	4
	Dibbets, Bakker, & Jolles (2006)	Picture switching	6.83(.53)	7	switch> nonswitch	13
	Halari et al. (2009)	Spatial switching	16.3(1.1)	21	switch > repeat	8
	Rodehacke et al. (2014)	Arrow switching	14.6(.3) r=13.7-15.5	185	switch > repeat	19

	Rubia et al. (2006)	Spatial switching	15 r=10-17	29	switch > repeat	5
	Wendelken, Munakata, Baym, Souza, & Bunge (2012)	Picture switching	10.56 r=8-13	20	switch > repeat	9
UPDATING	Beneventi, TØNnessen, Ersland, & Hugdahl (2010a)	Letter n back	13.5(0.5)	14	1 /2 back > 0 back	13
	Beneventi, Tønnessen, Ersland, & Hugdahl (2010b)	Phoneme n back	13.5(0.5)	13	2 back > 0 back	13
	Bennett et al. (2013)	Number n back	12.6(0.2)	11	2 back> 1 back	17
	Chang et al. (2004)	Visuospatial n back	14.4(3.2)	10	2 back > 0 back/control	6
	Ciesielski, Lesnik, Savoy, Grant, & Ahlfors (2006)	Categorical n back	6.1(0.55) r=5.11-6.6 & 10.1(0.45) r=9.1-10.5	17	2 back > 0/1 back	26
	Cservenka, Herting, & Nagel (2012)	Letter n back	14.18(0.7)	16	2 back > 0 back	3
	Cubillo et al. (2014b)	Letter n back	13.7(2.4) r=10-17	20	1 b > 0 b, 2 b > 0 b, 3 b > 0 b	20
	Li et al. (2014)	Categorical n back	10.9(2.7) r=8–16	27	2 back > 0/1 back	3

	Massat et al. (2012)	Number n back	10.05(1.28)	14	2 back > 0 back	17
	Malisza et al. (2005)	Spatial n back	r=7-12(1)	8	1 back > 0 back	13
	Nagel, Herting, Maxwell, Bruno, & Fair (2013)	Spatial & letter n back	13.11(1.78) r=10-16	67	2 back > 0 back	21
	Nelson et al. (2000)	Visuospatial n back	r=8-11.7	9	2/1 back > 0 back	10
	Robinson et al. (2014)	Letter n back	12.9(2.78)	15	2 back > 0 back, 3 back > 0 back	18
	Thomas et al. (1999)	Spatial n back	9.8 r=8-10	6	2/1 back > 0 back (individually assessed)	7
	Vuontela et al. (2009)	Location & Colour n backs	12.2 r=11-13	8	L2 back > L0 back & C2 back > C0 back	42
	Vuontela et al. (2013)	Face 1 back & scene 1 back	9.06 r=7-11	16	Face 1 back > rest & Scene 1 back > rest	18
	Yu et al. (2011)	Categorical n back	11.3(1)	15	2 back > basal stimulus	7

standard deviation is reported in brackets; r= range; congru= congruent; incongru= incongruent; GNG= Go-No/Go; b= back (e.g. 1 b); L= letter (e.g. L2 back); C= colour (e.g. C0 back); where ‘&’ is reported, two separate contrasts were included in the analysis

*For references of meta-analysis papers, see asterisked entries in references

2.3.3 Analysis

2.3.3.1 Activation-Likelihood Estimation (ALE)

BrainMap GingerALE software (version 2.3) was used to perform an ALE meta-analysis. Analyses were conducted based on Montreal Neurological Institute (MNI) coordinates and coordinates originally published in Talairach and Tournoux (1988) stereotactic-space were converted to MNI using the Lancaster transformation (Lancaster et al., 2007). ALE employs a coordinate-based meta-analytic technique based on voxel-wise foci of significant activation across the included studies. Activation foci from separate studies are mapped in a common stereotactic space to highlight consistent conjunction. The ALE method calculates the number of activation peaks across each region of the brain and compares this to a uniform activation distribution representative of a null hypothesis (which is when there are not enough peaks in a voxel to indicate that at least one peak truly activates in that voxel) (Wager, Lindquist, & Kaplan, 2007). The activation foci are then treated as 3D Gaussian probability distributions and are incorporated into a modelled activation map for each study. Data are filtered through a Gaussian kernel, which is sensitive to each study's sample size (Eickhoff et al., 2009; Eickhoff et al., 2011). It is important to note that while the ALE method considers conjunctive activation, a study with more participants can contribute more to the overall results (Wager et al., 2007). The ALE statistic means that within a given voxel, at least one or more significantly activated peaks apply (Turkeltaub, Eden, Jones, & Zeffiro, 2002). In the present study, the random sampling was subjected to 5000 iterations in order to compute a null distribution. This was then used to compare with voxel-wise ALE values to calculate statistical parameters (Nee et al., 2013). The ALE maps were thresholded at $p < 0.05$ corrected for multiple comparisons by false discovery rate (FDR, Laird et al., 2005) and further, a recommended cluster threshold of 100 mm^3 (Hill, Laird, & Robinson, 2014) was employed in the first-level analyses.

2.3.3.2 First-level analyses

First-level analyses on common executive (shared activation across tasks tapping inhibition, switching and updating executive processes) (Figure 2, part A) and each specific putative executive process (inhibition, updating and switching) were conducted. First-level analyses describe clusters that pass the applied threshold for significant conjunctive activation across studies included in each specified first-level group. These analyses were computed for both the whole sample and the child group separately.

2.3.3.3 Second-level Analyses

Second-level analyses were administered, which compare two first-level analyses, examining significant similarities and differences in activation. Second-level conjunction analyses reveal significant shared activation between two ALE maps, while second-level contrast analyses reveal significant non-shared activation between two ALE maps, by subtracting one ALE map from the other. To achieve these second level analyses whilst controlling for different sample sizes across studies, simulated data is created by pooling datasets and randomly dividing them into two groups of equal size, which are also equivalent to the original data sets' sizes.
The ALE images from the new datasets are then compared to each other, and resultant conjunctions/contrasts are compared to those in the true data.

Following many permutations, a voxel-wise p-value image is created and transformed to a z score to indicate significance (Eickhoff et al., 2011).

To examine the distinction between each executive process and common executive, the shared and non-shared activation between the common executive and each process was investigated. Since analyses pool data across studies, including the same study in common executive and process specific maps for second-level analyses, would introduce a bias towards significant conjunction. Thus, at the second level, analyses were conducted so as to prevent any individual study being included in two first level maps that were being compared. For example, when second-level analyses for updating and common executive were carried out, the “updating” map was compared to a “common executive (inhibit, switch)” map (Figure 2, part B).

Conjunction analyses to assess activation pertaining to the executive component of the executive process of interest— in this case, updating— were conducted (Figure 2, part C), as were contrast analyses which examined updating-specific activity (Figure 2, part D). Corresponding analyses were also administered for switching and inhibition. This technical necessity is thus consistent with our theoretical stance. Here, the common executive construct is defined as a system drawn on by all other executive processes (including the three specific processes focused on here but also others that are not the present focus). Thus, we are working from the assumption that shared activation across two or three or more individual executive processes should be equally capable of identifying the common executive component at a neural level.

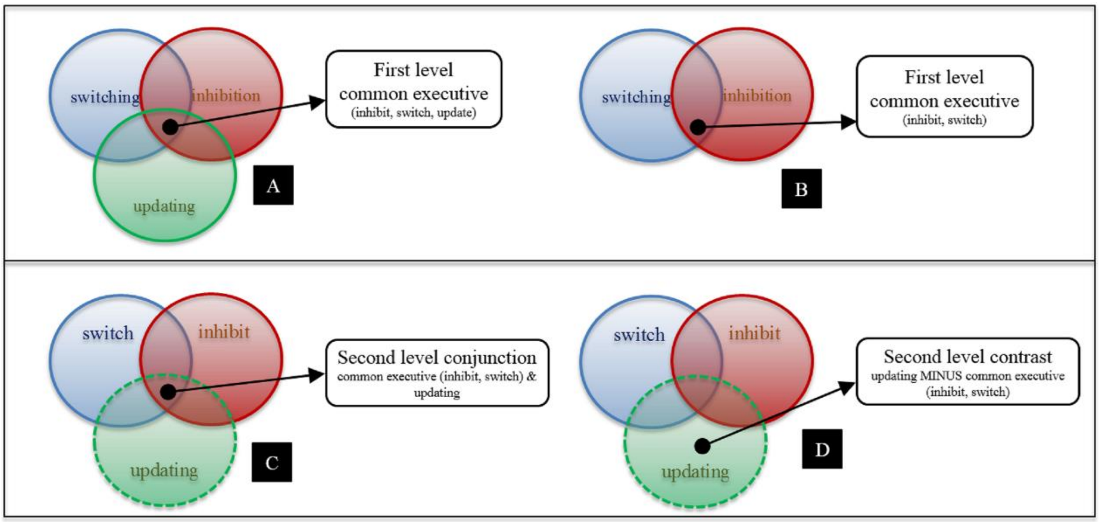

Figure 2. First and Second-level analysis design.

A. First-level Common Executive (inhibit, update, switch), B. First-level Common Executive (inhibit, switch), C. Second-level Conjunction Analysis for Common Executive (inhibit, switch) & Updating, D. Second-level Contrast Analysis for Common Executive (inhibit, switch) & Updating. N.B. There are statistical differences between A and C.

2.3.3.4 Control Analyses

Further second-level analyses, which we will refer to as "control analyses" were conducted to examine the putative similarities and differences between common executive, switching and updating. The control analyses were designed to control for the lower number of switching studies in the data set. These conjunction and contrast analyses compared subsamples of common executive, which were comprised of inhibition, switching and updating datasets with approximately 58 foci each (to match the maximum number of switching foci obtained), with subsamples of each specific executive process (again with approximately 58 foci each). Again, to reduce bias, each specific executive process subsample contained different studies from their comparative subsample included in the common executive dataset. The foci included in each common executive dataset were chosen at random, while ensuring that approximately equal numbers of foci from each EF task were represented in each subsample. Four different subsample datasets were computed for common executive and updating and thus, four control analyses were conducted. As there is only one switching dataset, we created four subsample datasets with inhibition and updating only (approx. 58 foci each) and contrasted these with the switching dataset, resulting in four separate analyses. Thus, for the examination of updating versus common executive activation, these control analyses included a common executive map derived from studies that included inhibition, switching and updating tasks. The analyses therefore provided a degree of verification of the assumption that common executive activity can be isolated from shared activation across tasks tapping two, three or more executive processes.

2.4 Results

2.4.1 Common Executive and Inhibition

2.4.1.1 First-level Common Executive Analyses

The first-level analysis ALE map for common executive in the whole sample demonstrated shared activation in 29 clusters, with the largest activation in the right and left middle and superior frontal gyri, the right and left supplementary motor area, right parietal regions, such as the supramarginal gyrus, the inferior and superior parietal gyri, the precuneus and the angular gyrus, as well as the left inferior and superior parietal gyri (Figure 3 and Appendix A).

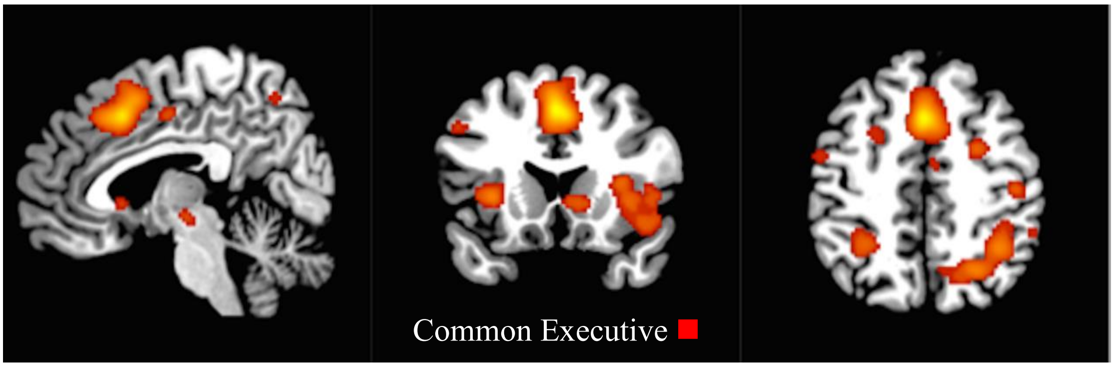

Figure 3. First-level Analysis for Common Executive in the child/adolescent group (x= 5, y= 17, z= 47). ALE maps showing the significant activation clusters of Common Executive for the child/adolescent sample (29 clusters).

The common executive first-level ALE map for the child group showed 30 clusters, and like the child/adolescent group, the largest cluster extended between the right and left supplementary motor area, the right and left middle cingulum and the right and left superior and medial frontal gyri. The same right parietal regions as the whole sample were activated, as well as the right middle frontal and precentral gyri (Figure 4 and Appendix B).

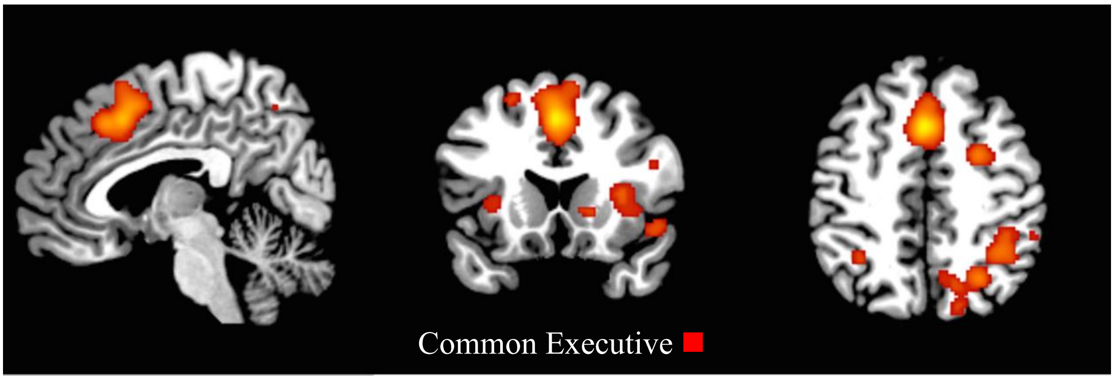

Figure 4. First-level Analyses for Common Executive in the child group (x= 5, y= 17, z= 47). ALE maps showing the significant brain activation for Common Executive in the child group (30 clusters).

2.4.1.2 First-level Inhibition Analyses

The whole sample ALE map for the inhibition first-level analysis indicated 20 activation clusters, with the largest clusters residing in the right and left superior and medial frontal gyrus and right and left supplementary motor areas, the right inferior frontal gyrus extending to the right insula and right superior temporal pole, as well as the right parietal regions (Figure 5 and Appendix A).

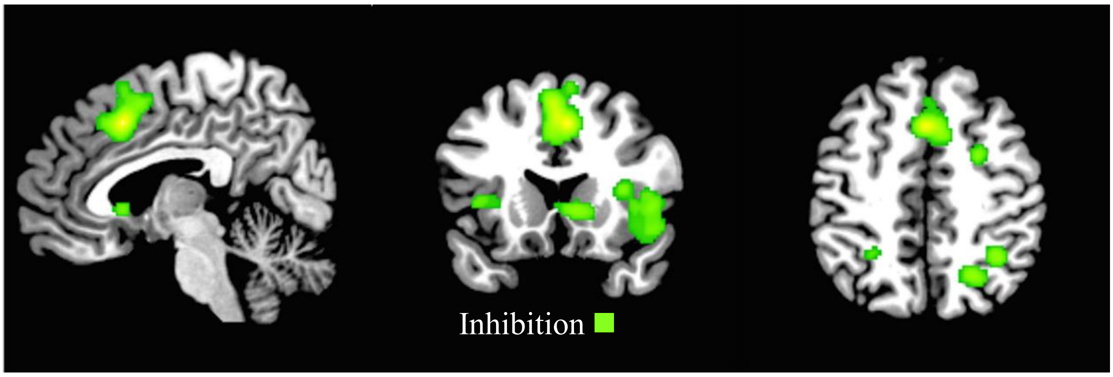

Figure 5. First-level Analyses for Inhibition for the child/adolescent group (x= 5, y= 17, z= 47). ALE maps reveal the significant activation clusters of Inhibition for the whole sample (20 clusters).

The ALE inhibition first-level analysis map for the child group revealed 18 activation clusters. The main patterns of activation were evident in the frontal areas, with clusters extending from the left and right supplementary motor areas, through the left and right medial frontal gyrus, to the left and right middle cingulum. (Figure 6 and Appendix B).

Figure 6. First-level Analyses for Inhibition for the child group (x= 5, y= 17, z= 47). ALE maps reveal the significant activation clusters of Inhibition for the child group (18 clusters).

2.4.1.3 Second-level Analyses

The conjunction analysis for common executive (update, switch) compared with inhibition revealed 10 shared clusters in the whole sample and 5 in the child group. The areas with the most significant activation in the whole sample included the left medial and superior frontal gyri, bilateral areas of the insula and parietal areas, and right sided activation in the precentral gyrus, claustrum and precuneus. Whereas, the areas with significant activation in the child group resided bilaterally in the medial frontal gyri and right sided activation in the cingulate gyrus, claustrum, the inferior parietal lobe and precuneus. However, the contrast analysis did not identify any significant differences for either sample. This is consistent with the view that inhibition is not separable from a common executive capacity (Appendices C and D).

2.4.2 Common Executive and Updating

2.4.2.1 First-level Updating Analysis

The first-level ALE map for updating displayed 25 clusters, with the main activation demonstrated in right and left frontal medial gyrus extending to the supplementary motor areas and middle cingulum. Other clusters included extensions from the right pars opercularis to the right precentral gyrus, the left and right inferior parietal lobule (with the right sided activation spreading to the supramarginal gyrus), the right and left middle frontal gyri to the superior frontal gyri and the right and left insula (Figure 7 and Appendix A).

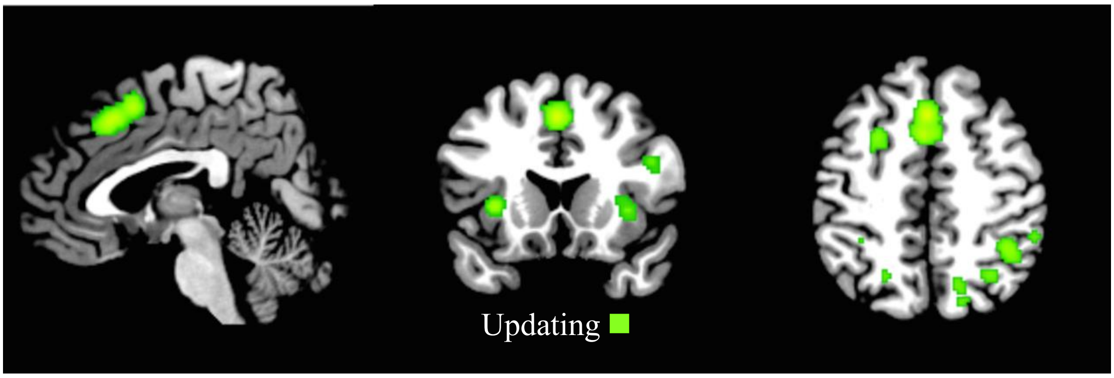

Figure 7. First-level Analyses for Updating (x= 5, y= 17, z= 47). ALE maps reveal the significant activation clusters of Updating in the child/adolescent group (25 clusters).

2.4.2.2 Second-level Analyses

Examining the common executive component of updating, the second-level conjunction analysis produced 8 conjunctive clusters in the whole sample (ranging between 40mm³ to 2576mm³ in size), mainly in the left and right superior frontal gyrus continuing to the medial frontal gyrus and extending to the right cingulum and right supplementary motor area, the left and right insula and the right inferior and superior parietal lobes (Figure 8 and Appendix E). The second-level conjunction analysis for the child group resulted in 6 conjunctive clusters, residing bilaterally in the medial frontal gyrus, the right cingulate gyrus, claustrum and right parietal areas (Appendix F).

To examine a putative "updating specific" component of updating, the second level contrast analysis revealed four contrast clusters (ranging between 144mm³ and 1136mm³) located in the right middle and superior frontal gyri, as well as the pars triangularis and pars opercularis in the right inferior frontal gyrus, and the left and right cerebellar crus I and II (Figure 8 and Appendix E). However, the second-level contrast analysis revealed no significant clusters in the child group.

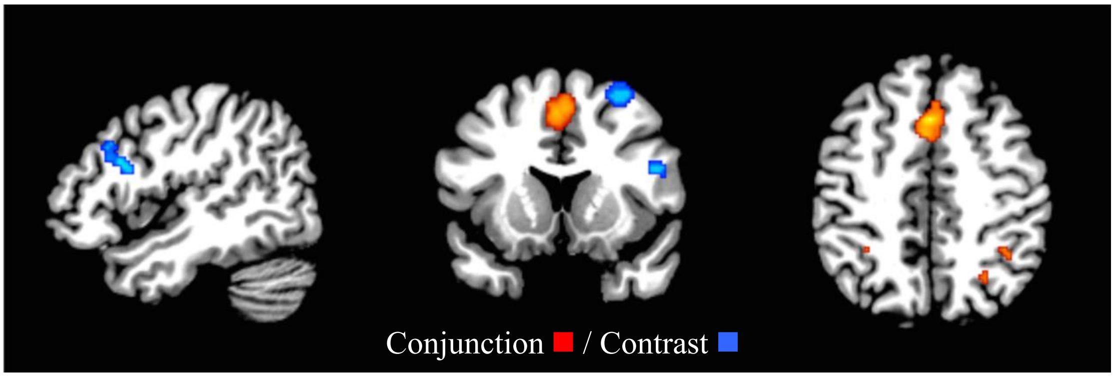

Figure 8. Common Executive (inhibit, switch) & Updating (x= 47, y= 13, z= 46). Significant conjunction and contrast analysis results for common executive (inhibit, switch) and updating. Regions of significant conjunction (8 clusters- red) and contrast (4 clusters- blue) are displayed. The clusters indicating non-shared activation were found when the common executive (inhibit, switch) dataset was subtracted from the updating dataset.

2.4.2.3 Control Analyses

As previously mentioned, to provide a closer matched point of comparison to the switching analyses and to test whether the pattern of significant shared and non-shared common executive versus updating activity that was identified above, exists when the common executive map includes updating tests, four second-level control analyses were conducted using foci-matched common executive and updating datasets. Two of the analyses identified contrast clusters when common executive was subtracted from updating. The first analysis found one contrast cluster (216mm^3)

extending between the right inferior and superior parietal lobe. The second reported two clusters, with the largest (304mm³) residing between the right middle frontal gyrus and the right precentral gyrus, and the smaller (104mm³), extending between the left cerebral crus I and left cerebellar lobule VI (Appendix H). These findings demonstrate that although the power of the analysis has been compromised, due to the lower number of foci included, updating-specific activity is still apparent.

2.4.3 Common Executive and Switching

2.4.3.1 First-level Switching Analysis

The first-level analysis for switching resulted in 4 activation clusters. The largest cluster was located in the right postcentral gyrus in the parietal lobe, with other clusters residing in the right middle cingulum, the left precentral gyrus extending to the pars opercularis in the inferior frontal gyrus and the left lingual gyrus spreading to the left calcarine (Figure 9 and Appendix A).

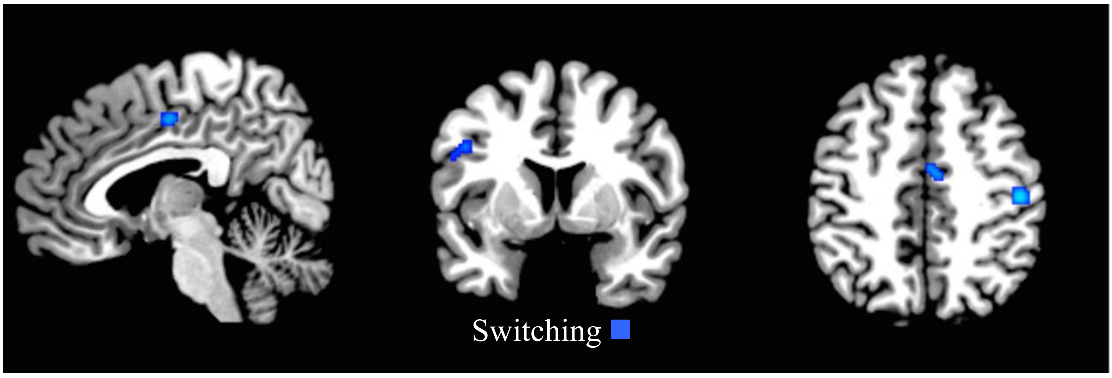

Figure 9. First-level Analyses for Switching (x= 5, y= 5, z= 46). ALE maps reveal the significant activation clusters of Switching in the child/adolescent group (4 clusters).

2.4.3.2 Second-level Analyses

Furthermore, to examine the putative common executive component of switching, the second-level conjunction analysis revealed one conjunctive cluster ($88mm^3$) extending between the left precentral gyrus and the left frontal inferior operculum. To examine the putative "switching-specific" component of switching, the second level contrast analysis revealed one contrast cluster ($192mm^3$) in the left lingual gyrus extending to the left calcarine (Figure 10 and Appendix G). These findings support the view that common executive and switching-specific components of switching may be separable at a neural level. Conjunction and contrast analyses were conducted for the child group, however, due to the low number of studies, no clusters pertaining to shared or non-shared activation were revealed.

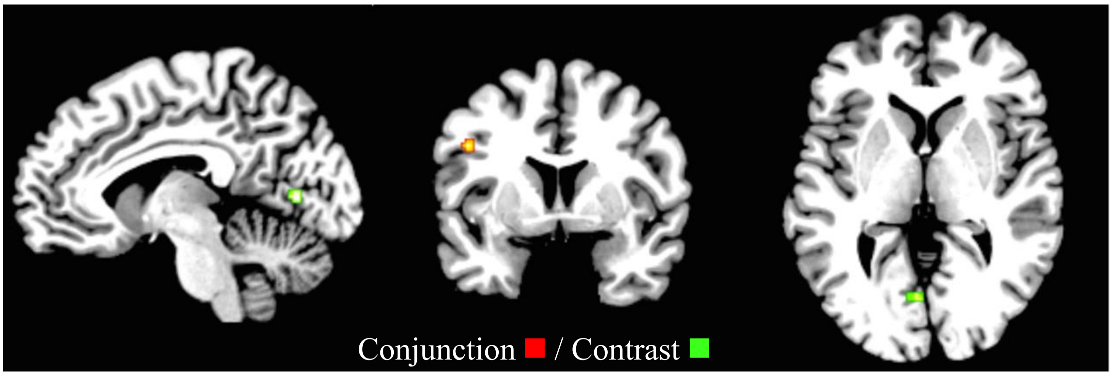

Figure 10. Common Executive (inhibit, update) & Switching (x= -7, y= 4, z= 1). ALE maps demonstrate the significant conjunction (1 cluster- red) and contrast activation (1 cluster- green) for common executive (inhibit, update) and switching. The contrast cluster was produced when the common executive (inhibit, update) dataset was subtracted from the switching dataset.

2.4.3.3 Control Analyses

Finally, four control analyses were also generated for the equivalent switching data, however, no significant differences were found in the contrast analyses.

2.5 Discussion

Here, an ALE meta-analysis investigated overlap and differentiation in neural activation pertaining to inhibition, switching, updating and the putative unitary 'common executive' capacity in children under the age of 18. Results suggest an overlapping yet distinct neural structure of executive function, as previously reported in adults (Collette, Hogge, Salmon, & Van der Linden, 2006). No inhibition-specific neural correlates unrelated to the common executive were identified in either the whole sample (child/adolescent) or in the child only group. Further, when updating and switching were compared to the unitary common executive, shared neural activation was demonstrated, pointing towards common executive components of switching and updating. However, such comparisons also revealed non-shared neural activation linked to updating and switching, pointing towards separable updating-specific and switching-specific entities in the whole sample. Specifically focusing on the child group relied on analyses with less power. Nevertheless, it is important that no evidence could be provided to support updating or switching-specific separable entities in the child group, despite substantial data being available to examine this possibility for updating.

When common executive activity was isolated based on shared activation across tasks linked to multiple executive processes, it revealed significant bilateral activation in fronto-parietal and regions of the supplementary motor area in the whole sample group. The corresponding analysis limited to the child group demonstrated significant activity in largely the same areas. These results are in line with previous findings, which indicate that these areas are activated during cognitive control tasks throughout the child and adolescent years (Chambers, Garavan, & Bellgrove, 2009). Further, activation in these regions has also been linked to conjunctive activity across inhibition, switching and updating tasks in adults aged 18-60 years (Niendam et al., 2012), and is consistent with the cognitive control 'fronto-parietal flexible hub' theory posited by Cole et al. (2013), which is based on functional neural connections engaged during cognitive control. Previous meta-analyses assessing EF activation have also generated results indicative of shared neural activity. One such analysis, conducted by Derrfuss et al. (2005), assessed the role of the inferior frontal junction (IFJ) during switching and Stroop task performance. Both analyses showed concurrence of activation in the IFJ, yielding support for an overlap of shared resources between the two executive process paradigms. Since the IFJ is part of the fronto-cingulo-parietal network, this study provides further support for the present results. Furthermore, as the study by Derrfuss et al. examines adult data, our results suggest a similar EF structure may be apparent in children.

In the present study, common executive activity coincided with activity linked to inhibition, isolated from shared activation across only inhibition tasks, in both the whole sample, as well as the child only group. However, for activity linked to inhibition tasks, larger clusters of right parietal activity appeared evident in the whole sample relative to those in the child group. Although our analyses could not make direct statistical comparisons between whole sample and the child group, these findings are generally consistent with progressive age-related increases in activation in parietal areas during inhibition engagement (Neufang, Fink, Herpertz-Dahlmann, Willmes, & Konrad, 2008; Rubia et al., 2006), and with a right laterality effect in adolescents compared to children (Houdé et al., 2010).

In line with the apparent similarities across common executive and inhibition related activation maps, our findings demonstrated areas of statistically significant shared activation across common executive and inhibition. Although, direct comparison between activation pertaining to inhibition and common executive has not been the focus, many previous studies have reported corresponding areas of activation for these constructs in child, adolescent and adult samples (Lei et al., 2015; Niendam et al., 2012; Vara, Pang, Vidal, Anagnostou, & Taylor, 2014; Velanova, Wheeler, & Luna, 2008; Wager et al., 2005).

Further, our finding of no areas of statistically significant difference across common executive and inhibition patterns of activation in either the whole sample or the child group is consistent with our hypothesis and in line with the cognitive theoretical view that inhibition and common executive are indistinguishable (Friedman et al., 2008, 2011b; Miyake & Friedman, 2012). This finding is important because it helps to reconcile some of the previous discrepant findings and contrasting theoretical approaches that have examined executive functioning in children. For example previous research investigating the structure and development of EF suggests a unitary factor representing a common underlying EF process is evident during early-middle childhood, after which distinct executive processes emerge (Shing, Lindenberger, Diamond, & Davidson, 2010). This finding is also supported by longitudinal evidence by Brydges, Fox, Reid and Anderson (2014). Other studies investigating preschool children, provide further support for this progressive differentiation of EF (Lerner & Lonigan, 2014; Tsujimoto, Kuwajima, & Sawaguchi, 2007). In addition, both Zelazo's cognitive complexity and control theory (Zelazo & Frye, 1998; Zelazo & Müller, 2002) and Munakata's theory (Munakata, 2001) describe EF changes in early childhood as possessing a unitary quality. However, in contrast, Diamond emphasizes the dissociative components of EF during development, yet, she also argues that periods of synthesis of multiple executive processes can occur during times of EF growth spurts in the preschool and early childhood years (Diamond, 2001; 2006). Inhibition is the factor most commonly identified in developmental EF latent variable analysis research, even in very young children, and this may be the first to develop (Garon et al., 2008). Therefore, the present findings suggest that what develops first may be the common component of EF, which is indistinguishable from inhibition during the developmental period. Therefore, executive dysfunction at an early age may be primarily governed by an inhibition deficit and due to the apparent strong links with behaviour problems, early intervention to improve inhibitory abilities may be key to minimizing the risk of development of clinically-relevant behaviours.

In examining common executive and updating-specific components of updating in children under 18 years, our findings point towards bilateral frontal, right parietal and subcortical activation reflecting the common executive component of updating. Importantly, updating-specific activation could be distinguished from that which corresponded to the common executive contribution in the whole sample group. Updating-specific activity was also frontal but specifically right sided, and further included areas of activation in the cerebellum. Previous work in adults has revealed greater activation in bilateral frontal regions as well as left parietal areas, when updating was compared to switching and inhibition (Collette et al., 2005) pointing towards some correspondence across children and adults in this respect. Previous work in adults has attempted to isolate an updating-specific process from common executive at a neural level using relational analyses between indices derived from performance on cognitive tests, and functional and morphometric indices of brain networks (Reineberg, Andrews-Hanna, Depue, Friedman, & Banich, 2015; Smolker, Depue, Reineberg, Orr, & Banich, 2015). However, relationships between individual differences in updating-specific ability and a resting state functional connectivity network were not demonstrated consistently across all of these indices. It was therefore proposed that updating-specific ability may rely more on a specific area involved in WM and less on connectivity between regions.

Miyake and Friedman (2012) posited that the concept of an updating-specific process, and the abilities it taps, is less clear than the other executive processes, yet, they have suggested 'effective gating of information' and 'controlled retrieval from long-term memory' as integral components. This proposal is consistent with work that has examined transformation, substitution – in line with Miyake's effective gating – and retrieval, as updating subsidiary components (Bledowski, Kaiser, & Rahm, 2010; Ecker, Lewandowsky, Oberauer, & Chee, 2010; Y. Zhang, Verhaeghen, & Cerella, 2012), and allows updating to be conceptualized with respect to performance on measures of WM capacity, which similarly draw on retrieval (Ecker et al., 2010; Unsworth & Engle, 2008). All of the updating tasks included in the present meta-analysis (n back tasks) and the task employed by Reineberg et al. (2015) and Smolker et al. (2015) (keep track), require retrieval (Linares, Bajo, & Pelegrina, 2016). Thus, since right prefrontal brain regions have been particularly implicated in WM capacity (Prabhakaran, Narayanan, Zhao, & Gabrieli, 2000; RepovŠ & Baddeley, 2006; Zhang et al., 2004), the present findings are consistent with the view that the updating specific process identified may rely heavily on neural architecture involved in WM capacity. Previous research has suggested that computerized WM training can increase WM capacity and improve use of WM in everyday life (Spencer-Smith & Klingberg, 2015), but there has been debate around whether such improvements may transfer to, for example clinical benefits in developmentally disordered populations (Melby-Lervåg & Hulme, 2013). Future work in this area that considers the presently suggested relationship between updating specific EF and WM capacity may be productive in informing on the scope of potential effects of WM training and their applicability to atypical child populations.

The present results also pointed towards a role of the cerebellum in updating-specific processes. Cerebellar activation has been linked to performance monitoring during task engagement, in particular, post-error processing in relation to motor responses (Peterburs et al., 2015). All of the presently included updating tasks incorporated button-press responses, consistent with involvement of post-error motor response processes. Thus, it is possible that the present involvement of cerebellar activity reflects a task specific process, as have been highlighted as important factors to consider in this kind of functional neuroimaging analysis (Chein et al., 2011; Tomasino & Gremese, 2016). In considering the role of task specific processes, it is interesting to note that the work highlighting right prefrontal neural areas as important in WM capacity has suggested a particular role for cross-modal integration of information for WM (Prabhakaran et al., 2000; RepovŠ & Baddeley, 2006; Zhang et al., 2004). Since the updating tasks involved in the present meta-analysis also involve integration of information across domains, one possibility that warrants further examination is the degree to which updating-specific processes may be inherently task specific.

Notably, our results revealed no updating-specific activation in the child group suggesting a possible distinction between the degree to which updating-specific neural processes can be differentiated in children under 12 years, and those under 18 years. When examining updating subcomponents, age related changes in neural activation linked to retrieval but not substitution or transformation, have been demonstrated across children, adolescents and young adults (Linares et al., 2016). This is consistent with development in working memory capacity throughout childhood and adolescence following a linear trajectory, with subtle adjustments, in particular in increased capacity, taking place during adolescence and early adulthood (Gathercole et al., 2004; Satterthwaite et al., 2013). Thus, one interesting possibility highlighted by the present findings is that as working memory capacity develops over the course of childhood, so too does the relationship between a common executive component of updating and updating-specific processes, which allows updating tasks to be performed successfully. A focus for future research may be to assess the development of both dimensions of updating during childhood, and examine if there is a temporal link between improvements in working memory capacity and the advancement of the executive component of updating and updating-specific abilities.

Our first-level analysis of switching related activation pointed towards involvement of right parietal-cingulo, left frontal and left occipital (lingual gyrus) regions, These findings are consistent with previous meta-analyses examining switching-related neural activation in adults (Buchsbaum et al., 2005; Collette et al., 2005; Niendam et al., 2012) and so suggest a general correspondence between children and adults in this respect. Unfortunately, due to the low number of switching studies included in the analysis, a comprehensive examination of switching related activation in children under 12 years only was not possible. The present evidence for both a common executive component of switching in the whole sample group – which involved left frontal activation – and a switching-specific component is consistent with previous work in adults (Herd et al., 2014; Reineberg et al., 2015; Smolker et al., 2015) and supports an integrative view of switching in children under 18 years. However, whilst previous work – if employing distinct methodologies – has pointed towards parietal involvement in a switching-specific process in adults (Collette et al., 2005; Reineberg et al., 2015), the presently identified switching-specific activity was limited to left occipital regions (lingual gyrus). In interpreting these results, it is important to consider the relatively small amount of data available on switching tasks for inclusion in the present meta-analysis. However, since all of the presently included switching tasks relied heavily on visual stimuli, the finding is consistent with increased susceptibility to task modality being a feature of less developed cognitive processing (Fisher, 2011; Irving, González, Lillakas, Wareham, & McCarthy, 2011). Interestingly, deficient switching demonstrated in individuals with a particular genetic neurodevelopmental disorder has been associated with greater involvement of occipital, but reduced involvement of frontal parietal brain regions in switching (Woodcock et al., 2010). Thus, an important area for future investigation will be how switching-specific processes change over the course of development, and whether the deficient switching that appears to be evidenced in several neurodevelopmental disorders (Van Eylen et al., 2011; Woodcock et al., 2009), reflects a deficiency in switching-specific processes, the common executive component of switching, or both.

Overall, these findings demonstrate that the neural substrates of executive function in children are part of a superordinate cognitive control network, mainly represented in the fronto-cingulo-parietal cortices, yet, selective recruitment within these areas and others, such as subcortical regions, is evident when executive process-specific capacity is analysed. These results are in line with previous meta-analytic research examining EF in adults (Collette et al., 2005; Niendam et al., 2012).

2.5.1 Limitations

Not dissimilar to other brain imaging meta-analyses, methodological considerations are evident. A limitation of the ALE method is that, with regards to statistical thresholds, inter-study differences are not accounted for- perhaps most notably, the power of each study. Further, this coordinate-based technique does not consider the extent of activation for each cluster but activation location only. Cluster based thresholding does not allow for precise spatial specificity, thus, we must be careful not to make inferences about the statistical significance of a particular location within a given cluster (Woo, Krishnan, & Wager, 2014). Findings should also be regarded as a depiction of positive results, bearing in mind negative results cannot be generated (Cortese et al., 2012).

It is also important to note the absence of a separable analysis of adolescent only data. This omission limits the level of comparison drawn between the two age groups and therefore, questions the strength of the argument of the current study that EF structure changes throughout development. Further, while the lack of dissociate executive processes in the child group provides an argument for these structural changes, it must be noted the occurrence of such may be due to the lower number of foci included, and consequently the lower statistical power associated with the child group analyses.

In addition, the present study did not account for task content (e.g. stimuli type- spatial, letter, number etc., or response type- motor, verbal). Previous meta-analyses have found EF activation to be task-dependent (Kim, Cilles, Johnson, & Gold, 2012). For instance, Simmonds, Pekar and Mostofsky (2008) reported additional 'complexity' related activation when they compared simple and complex go/no-go tasks which varied in terms of their working memory demands. Likewise, Swick, Ashley and Turken (2011) acknowledged the need to consider differential processing demands elicited by executive tasks. Upon examination of the neural activation of go/no-go and stop-signal tasks, the authors found concurrent activity for both tasks, whereas non-concurrence appeared in areas of the frontoparietal and cingulo-opercular networks respectively. It is unfortunate that we were restricted in which tasks we could include in our analysis, as it is possible that the differential processing demands of those tasks had an influence on the patterns of activity identified. Indeed, our results may indicate that activation relating to switching-specific and updating-specific abilities reflect processing demands necessary for respective task completion. Yet, since our analyses did not rely on only one particular task, the task-specific influence on our results was minimized. Nonetheless, in order to demonstrate a more complete neural picture of EF performance, future meta-analytic study should assess neural activity associated with EF task-specific components, which may in turn help to promote more effective EF measurement.

A further limitation of the present study is the broad age range used in the dataset. In addition to this, as some papers included in the analysis did not report detailed age demographics (see table 2), there may be variability in the overall age range reported. Moreover, a clear limitation is the lack of switching studies that were available for inclusion. Thus, the present results relating to switching, particularly in the higher-level comparisons with other executive processes, should be treated with caution. While there has been considerable interest in examining the neural correlates of switching using fMRI, most of these studies do not include data from typical children and/or have not examined the contrasts appropriate for isolating the presently studied construct of switching. This may be because switching has been examined at a more sub-componential level e.g. the focus of the literature does not seem to be in examining switching per se but instead how it works. Perhaps if a model of EF can be applied to children, which includes switching as a basic construct, this might facilitate more future attention on the construct of switching itself.

Finally, it is important to acknowledge the assumption made in the present analyses – based on our theoretical position – that isolating common executive activity based on tests tapping only two putative executive processes (Figure 2, part B), served an equivalent role to isolating such activity based on tests tapping three or more executive processes (Figure 2, part A). We were able to test this assumption on a small scale in our control analyses of updating, which pointed towards consistency with our primary analyses. We also conducted further second-level analyses which examined the shared and non-shared activation between maps of common executive, which included all tasks pertaining to inhibition, switching and updating and one of the executive processes, to assess whether inclusion of this data would bias the patterns of overlap and distinction. As expected, results showed shared overlap when each executive process was compared to the 'inclusive' common executive map (with more significant clusters identified than in the primary analyses reported here), but no distinct clusters in contrast analyses in any of the analyses (Appendices I, J and K), supporting the existence of a bias towards identification of conjunctive activation if any of the same studies are included in two maps compared in second-level analyses. These findings support our assumption. Nevertheless, the nature of the limitation itself meant that it could not be tested directly (i.e. second-level comparison of a common executive map comprising inhibition, switching and updating studies, to one comprising only the inhibition and switching studies, would be biased towards identification of conjunctive activation).

2.5.2 Conclusion

In conclusion, the findings from this meta-analysis support the application of the structural integrative model of EF, as posited by Miyake et al. to a developmental context. However, due to the complex nature of development and the changing structural climate of EF throughout childhood (Brydges et al., 2014; Howard, Okely, & Ellis, 2015; Lerner & Lonigan, 2014; Shing et al., 2010; Tsujimoto et al., 2007), perhaps a new systematic developmental model, which encourages careful measurement of common executive and executive process-specific components, should be employed. Previous meta-analytic study has reported effects of task modality on EF performance in children (Booth, Boyle, & Kelly, 2010), however, the influence of non-executive factors on EF performance at a neural level has not yet been investigated. As a result, future examination is warranted, which could subsequently inform on valid EF measurement. Only then, can we begin to systematically amalgamate knowledge acquired through understanding the neural infrastructure of EF in development, to behaviour– in particular, executive dysfunction in clinical populations.

Chapter 3

Investigating non-executive task demands in EF neural activation in children: A meta-analysis of fMRI data

3.1 Introduction

"It is quite possible that striking differences in nonexecutive processing requirements (e.g., language and visuospatial processing) have simply masked the existence of some underlying commonalities among the chosen executive tasks…Because executive functions necessarily manifest themselves by operating on other cognitive processes, any executive task strongly implicates other cognitive processes that are not directly relevant to the target executive function. For these reasons, a low score on a single executive test does not necessarily mean inefficient or impaired executive functioning."

[Miyake et al., 2000]

As highlighted in the above quote by Miyake et al. (2000) in their highly influential paper, executive function relies on the processing of other lower-order cognitive functions. It is conceptualised that EF operates indirectly on one's experience and because of this and the underlying hierarchical complexity of functions which make up EF, these processes are not measurable in isolation. The 'task impurity problem' (as described in the above quote) is an issue for quantifying many variables in cognitive psychology, yet especially as EF by its very nature eludes direct measurement, inconsistent findings have resulted in the area of EF assessment

(Burgess & Stuss, 2017; Snyder, 2013; Van Eylen, Boets, Steyaert, Wagemans, & Noens, 2015).

In order to alleviate task impurity on EF measurement, researchers have adopted varying statistical frameworks and approaches. In the above study, Miyake et al. (2000) administered three tasks to measure each of inhibition, switching and updating executive processes, while ensuring that differing non-executive processes were being tapped across tasks. For example, the switching tasks utilised were the number-letter task, the plus-minus task and the global-local task. A brief summary of the tests utilised in the Miyake battery is displayed in table 3. The differing non-executive components across tests allowed researchers to more effectively measure the common variance between task performance, which should represent executive engagement. Moreover, the researchers applied a latent variable approach to extract the 'pure' executive function effect from the non-executive variance associated with the individual tasks (e.g. articulation speed or word processing). A latent variable is an unobservable variable which is not directly measured, yet the score can be inferred from performance in tasks it influences (Friedman, 2016). It was argued that this method reduced the inherent difficulty in measuring executive processes that arises from the fact that single tasks tapping an executive process necessarily also place demands on non-executive processes. This approach supports the use of a number of tasks for each EF process, as EF tasks typically possess low inter-correlations scores, due to non-EF variance within tasks (Friedman & Miyake, 2004). This latent variable approach in measuring EF has been applied substantially since this initial work (Friedman et al., 2008, 2011; Friedman & Miyake, 2004; Jester et al., 2009; Rose, Feldman, & Jankowski, 2012; Schiebener et al., 2014), and because of its minimisation of the task impurity problem, it is largely considered the method of choice for the measurement of EF. However, this approach does have its limitations, particularly in the measurement of EF in clinical populations, due to the difficulty in recruiting sufficient clinical sample sizes in order to satisfy such an analysis (Snyder, 2013).

Table 3. Brief description of executive tests included in the Miyake battery

	Executive test description
<u>Inhibition</u>	
Anti-saccade task	Participants were required to fixate on a point on-screen and inhibit looking at the target stimulus (an arrow) presented on either side of the screen, while indicating the direction of the arrow by a button-press response (90 trials).
Stop-signal task	This task consisted of 2 blocks of trials. In the first block, participants were asked to categorise words either as an animal or non-animal by button-press (48 trials). The second block required participants not to respond (i.e. to inhibit categorising) when a tone was presented in 48 of the 192 trials.
Stroop task	Participants were required to verbally name the colour of a colour word stimulus (neutral, incongruent and congruent trials presented) (72 trials in total).
<u>Switching</u>	
Plus-minus task	3 lists of 30 two-digit numbers were presented on paper. The first list required participants to add 3 to each number & write the number down. They had to subtract 3 from the numbers displayed on the second list, and then alternate subtracting and adding 3 to the numbers on the third list. Completion of the lists were timed and the cost of switching in the third list was determined by the difference in completion time in the alternating list in comparison to the average completion time of the other lists.
Number-letter task	A number-letter pair was displayed in 1 of 4 quadrants on-screen. When displayed in the top 2 quadrants of the screen, participants were asked to indicate whether the number was odd or even, via button-press, and whether the letter was a vowel or consonant when displayed in the bottom quadrants of the screen. 3 blocks were completed, with only the third block (128 trials) requiring switching.

Local-global task	A geometric figure was displayed on-screen, which depicted a global figure (e.g. a triangle) which was also composed of smaller 'local' figures (e.g. squares). Participants were asked to verbally indicate the number of lines (i.e. 1 for a circle, 2 for an X, 3 for a triangle, and 4 for a square) in the global figure when the figure displayed was blue. And the number of lines of the local figure when it was black. 96 target trials were presented, with half of trials requiring switching.
Updating	
Keep track task	15 words (including exemplars of 6 categories [animals, colours, countries, distances, metals, and relatives]) were randomly presented in serial order. Target categories were displayed at the bottom of the screen. Participants were required to remember (& write down) the last word presented in each of the target categories. 3 trials with 4 target categories and 3 trials with 5 target categories were presented.
Tone monitoring task	25 tones (consisting of 8 high-pitched, 8 medium-pitched, 8 low-pitched & 1 tone randomly selected from the 3 pitches) were presented in 4 blocks of trials. Participants were required to respond when the 4th tone of each pitch was presented.
Letter memory task	Several letters were presented serially and participants were asked to recall the last 4 letters displayed. The participants were required to verbally rehearse the last 4 letters by incorporating the most recent letter and dropping the 5th letter back (most distantly presented). 12 trials for a total of 48 letters recalled were administered.

3.1.1 The EF battery approach

Nevertheless, the recommendations offered by this team to promote effective EF measurement, elicited increased efforts in the development of batteries of EF tasks. EF batteries aim to facilitate careful EF (and non-EF) measurement across tasks, by incorporating multiple tasks to measure each EF process, while using a wide variety of non-EF components across tasks, as well as administering different instruments to measure EF (Van Eylen et al., 2015). In a further attempt to reduce task impurity interference, researchers have also utilised the same non-EF aspects across tasks which measure different EF domains, as a way to find executive differences and thus, extract a 'purer' measurement (Plasschaert et al., 2016). Many classic EF tasks are multidimensional in nature, in that they measure more than one executive process. Examples include the Wisconsin Card Sorting Test (WCST), the Trail Making Test, the Tower of Hanoi and the Matching Family Figures Test (Booth et al., 2010). Understandably this complexity poses further difficulty for achieving an accurate and 'pure' measurement of executive processing. Therefore, by way of utilising simple object-categorisation stimulus-response paradigms to measure EF, EF batteries overcome such problems, and in turn, ensure reliable distinct executive process assessment, while reducing demands on non-executive processing.

The battery approach has demonstrated impressive content validity and substantial construct validity (Henry & Bettenay, 2010) via agreement with measures of relevant everyday behaviours. Considering the benefits of EF batteries on the effective measurement of EF, it is not surprising the use of such tools is especially important for assessing EF in clinical populations, particularly those with neurodevelopmental disorders. Notwithstanding, while the battery approach reduces the deleterious impact of non-executive noise in EF scores (i.e. task modality features), idiosyncratic task-specific demands are still relied upon in the assessment of executive processing. And accordingly, may result in more pronounced difficulties in accurate EF assessment in children with mental disorders. To address this problem, a pilot EF battery was created by members of our research team, which was based on the Miyake battery, however with adaptations to avoid the pitfalls concerning its use with neurodevelopmental populations. For example, Miyake et al. (2000) utilised a Stroop test to measure inhibition ability. The Stroop test measures inhibition of the dominance of the participant's reading response to a written word. However, specific word reading difficulties are elevated across children with several mental disorders (Carroll, Maughan, Goodman, & Meltzer, 2005; Willcutt et al., 2002) and as such, reading difficulties could affect performance on the Stroop test independently of a child's inhibition ability. Comparably, one of the switching tests employed in the original Miyake battery comprises a number classification task. Thus, it is possible children's mathematic abilities, which are associated with EF (Clements, Sarama, & Germeroth, 2016) and are anomalous of various mental disorders (Capano, Minden, Chen, Schachar, & Ickowicz, 2008; Shalev, Auerbach, Manor, & Gross-Tsur, 2000), could influence switching performance in this task. The pilot battery created in this work avoided such potentially confounding test characteristics. It is important to note the development of the new online battery of EF tests, informed by the current work, is part of a wider research project. Therefore, a full justification for its development is outside the scope of this work and thus, what is presented in this thesis, in relation to the battery, is intended to act as a summary.

3.1.2 The effects of task modality on EF measurement

Many studies have examined how the modality of the stimuli and responses embedded in EF tasks affect executive performance and in turn, EF measurement. There is evidence to suggest modality impacts the processing of cognitive control task demands, particularly in conflict adaptation and conflict resolution (Yang et al., 2017), with features of task-irrelevant stimuli interfering with the transfer of cognitive control (Braem, Abrahamse, Duthoo, & Notebaert, 2014).

Furthermore, specific stimuli-type influences on EF performance have been reported in clinical populations. In individuals with ASD, frontostriatal activity during EF tasks can be contingent on stimulus type, with increased activation for social stimuli (i.e. faces), and decreased activation for non-social stimuli (Sabatino et al., 2013). . Contrastingly, when stimuli vary according to assumed capacity to induce arousal, stimulus type appears not to impact inhibition performance (Kuiper, Verhoeven & Geurts, 2016). Combining social and emotional stimuli characteristics however, Ibáñez et al. (2011) found an association between face valence stimuli and EF processing in participants with ADHD. Finally, in populations with reading difficulties, use of verbal vs non-verbal stimuli/responses appears to influence EF task (Peng, Sha, & Li, 2013) Thus, evidence suggests that different dimensions of stimuli characteristics can affect EF performance to different degrees, particularly in clinical samples.

As well as exploring the importance of task modality on executive processing as a general construct, investigations into how such features may impact distinct executive process performance has ensued. For switching, Kübler, Murphy, Kaufman, Stein and Garavan (2003) outlined neural correlates of verbal and visuospatial task aspects. Furthermore, behavioural evidence has implied partially modality-specific frontal recruitment (Hunt & Kingstone, 2004). For updating, Kreutzfeldt, Stephan, Willmes and Koch (2017) found modality-specific effects in neural engagement. However, considering inhibition, supramodal networks have been reported, utilising both visual and auditory stimuli (Walther, Goya-Maldonado, Stippich, Weisbrod, & Kaiser, 2010). And a flanker inhibition task has been used to suggest that associated neural lateralisation can be explained by the inhibition demands rather than the verbal or non-verbal nature of the task (Morimoto et al., 2008). The inhibition findings have been mirrored in those linked to general EF, where supramodal networks (utilising visuospatial and auditory tasks) have been identified (Spagna, Mackie, & Fan, 2015). Thus, the impact of task modality on EF performance varies, when distinct executive processes are assessed. And it could be argued the pattern pertaining to the extent to which non-executive task features interfere with EF performance is reflective of the structural composition of EF as discussed in the previous chapter, with more impact occurring in dissociable processes (i.e. switching and updating).

Another consideration in examining task modality effects is the modality compatibility, that is, the similarity between stimuli-response sensory modes (e.g. visual-manual and auditory-vocal) of EF tasks. Previous research shows that when modality is incompatible in task sets during switching, increased switching costs are evident (Stephan & Koch, 2010, 2015; Stephan, Koch, Hendler, & Huestegge, 2013) suggesting modality-specific effects on switching performance. Recently, Peng, Kirkham and Mareschal (2018) assessed the multisensory effect on executive processing in development. They found markedly similar effects in modality-switching during an EF switching task in 4-year olds, 6-year olds and adults. These results led the researchers to propose relative cross-modal maturity is achieved between the ages of 4 and 6 years old. Therefore, this work suggests interference from modality-specific task demands is largely stable throughout development.

3.1.3 The present study

Considering the battery approach assumes *real* EF reflects what is not specific to test-type/stimulus-type, and that evidence indicates that different tasks/stimuli draw on differential neural underpinnings, the present study aims to again investigate EF fMRI activation in children (assessing both the common executive and specific executive processes) but shifting the focus to examine stimuli-type and test-type at a neural level. In comparison with other executive processes, there is arguably the greatest variation in tasks used to measure inhibition reported in the literature, and indeed, this is true for the papers included in the meta-analysis presented in the previous chapter. Therefore, the present analyses will examine the contributory effect of each inhibition task on neural activation representing the common executive. Stimuli-type analyses will be conducted for common executive and updating activation. However, due to the small amount of switching studies included in the dataset, corresponding analyses pertaining to specific switching activation will not be carried out.

Exploring activity at a stimuli-type and test-type level will provide an opportunity to assess the biological validity of the stimuli/tests for measuring EF across studies. We assume that tests recruiting more shared activity across multiple tests are better EF measurement tools. This assumption is based on the idea that shared activation across tests represents executive activity and thus, the greater the executive activity, the less interference from idiosyncratic task-specific demands, whether it be stimuli mode or task paradigm. Therefore, in this work, the “best” tests/stimuli can be identified as the modalities that recruit the largest shared neural networks. Accordingly, findings may inform suitable amendments to the aforementioned pilot EF battery. It is hoped that the composition of a new online battery of EF tasks will enhance pure and accurate EF measurement in children. Again, BrainMap GingerALE software (version 2.3) was used in this fMRI meta-analysis.

3.2 Methods

3.2.1 Design

The methods used in this study were largely similar to the previous meta-analysis outlined in Chapter 2. The same 49 papers (53 experiments) which present fMRI activation relating to inhibition, switching and updating performance by children and adolescents (aged 6 - 18 years), were included. Again, separate maps were created to illustrate the activation shown across the different executive domains, with the inclusion of a “common executive” map which demonstrated activation across all EF tasks (incorporating inhibition, switching and updating). The focus of the present study was to examine activation pertaining to test-type (for inhibition e.g. Stroop, anti-saccade) and modality-specific aspects of the executive tasks (i.e. stimuli-type).

Studies were discriminated by the modality of the stimuli used in each task and the type of inhibition test used (for inhibition studies). Four modalities were identified across the studies: tasks using picture, spatial, arrow or letter stimuli. And six inhibition tasks were employed, which included, go-no/go, Stroop, stop, anti-saccade, flanker and Simon tasks. The relative contributions of the different task and stimuli types to the corresponding executive activation maps was assessed.

3.2.2 Study Selection

See previous chapter for details regarding study selection. All papers included in the previous meta-analysis were used in the current study. It is important to note that while the same studies were included in the two meta-analyses, given the focus of modality and test type in this meta-analysis, there was an increased number of contrasts included in the common executive map. This was due to studies utilising multiple modalities across a number of EF tasks. And although this meant including data across maps from the same participants, the differing modality demands across EF tasks justified the inclusion of such data.

3.2.3 Analysis

3.2.3.1 Activation-Likelihood Estimation (ALE)

Again, Brainmap GingerALE software (version 2.3) was utilised to conduct the ALE meta-analysis. Talairach and Tournoux (1988) coordinates, as reported by a number of studies were converted to Montreal Neurological Institute (MNI) coordinates through the use of the Lancaster transformation (Lancaster et al., 2007) so all analyses were MNI-based. ALE maps followed the same statistical parameters, which included thresholding. See the previous chapter for a detailed description of the ALE methodology.

3.2.3.2 Stimuli-type First-Level Analyses

First-level analyses display clusters which pass the threshold for significant conjunctive activation across studies. A first-level analysis on shared activation pertaining to common executive capacity (all studies included) was conducted and thus, treated as a comparison map for further analyses. For this study, the common executive map separated the contrasts (61 in total) and treated them as if they were separate studies, as some studies utilised differing task-modalities, e.g. Nagel, Herting, Maxwell, Bruno and Fair (2013) reported activity relating to performance on a spatial n back and a letter n back (see Table 2 in previous chapter). Further analyses were carried out to assess activation relating to the common executive when specific stimuli-types were excluded (e.g. tasks utilising letter stimuli, picture stimuli, spatial stimuli and arrow stimuli). The maps relating to these datasets were named ‘Common executive minus letter’, ‘Common executive minus picture’ etc. These analyses allowed comparison between the contribution of each stimulus mode to executive activation, as measured through activation cluster volume. Comparable analyses were carried out to assess activity pertaining to updating performance across all task modalities, and activity pertaining to updating when a stimulus type was excluded, by way of assessing the contribution of each task mode to executive activation. Unfortunately, there were not enough switching studies included in the dataset to assess the input of task modality on switching activation.

Further maps were created to illustrate activation differences between each task mode across the common executive. Additionally, to ensure results were not biased by differential number of foci included between modality-specific analyses, matched foci analyses were conducted. These analyses matched foci to the included task mode with the smallest number of foci (in this case, spatial stimuli which were linked to 98 foci), by randomly selecting the foci to be incorporated in each matched modality-specific map.

3.2.3.3 Stimuli-type Second-Level Analyses

Second-level analyses compared two first-level maps to assess significant overlap in activation as well as differential activity between maps. Therefore, conjunctive activity relates to significant shared activity between the two ALE maps in question. See previous analysis for information regarding the underlying methodology for conducting second-level ALE analyses. Therefore, second-level analyses were carried out to assess the conjunctive activation between the common executive and each modality-specific map. Although it is not optimal to compare maps which incorporate the same studies (e.g. studies in the letter stimuli map are also included in the common executive map), these analyses were carried out to further examine whether the differing number of foci across maps bias the results pertaining to input of each task mode on executive activation.

3.2.3.4 Test-type Inhibition Analyses

First-level analyses were conducted to assess activity relating to each inhibition task (i.e. Stroop, go-no/go, Simon, flanker, anti-saccade, stop task). To assess the contribution of each inhibition task, and thus rank each task in terms of their input to executive engagement at a neural level, maps showing the simultaneous addition of each task were created (e.g.flanker map, flanker+stop map, flanker+stop+anti-saccade map, flanker+stop+anti-saccade+go-no/go map, and so on). The above is an example of one combination of simultaneously including inhibition tasks. Five combinations which alternated the order of addition were created e.g. Combination A= go-no/go, Stroop, Simon, flanker, stop, anti-saccade, Combination B= flanker, stop, anti-saccade, go-no/go, Simon, Stroop, and so forth. The average cluster volume added from each task across the five combinations was then calculated and tasks were subsequently ranked.

3.3 Results

3.3.1 Stimuli-type First-Level Analyses

3.3.1.2 Common Executive and Updating

The first-level ALE map for common executive showed 28 clusters with a total cluster volume of 40672mm^3. The ‘common executive minus letter’ map illustrated that the cluster volume reduced to 26936mm^3 when tasks utilising letter stimuli were not included. In contrast, maps representing common executive when spatial tasks, arrow tasks and picture tasks were excluded, demonstrated that cluster volume reduced somewhat less in size (Table 4). Similarly, when letter stimuli were not included in the updating map, cluster volume was only 14976 mm^3, whereas when updating tasks with spatial and picture stimuli were not included in the updating analyses, the cluster volume found was 19344mm^3 and 20808mm^3 respectively. These findings indicate that executive tasks using visual letter stimuli (in comparison to arrow, picture or spatial stimuli) recruited a larger proportion of common executive, and updating activation.

Table 4. First-level Common Executive and Updating Stimuli-type Exclusion Analyses

First-level Map	No. of contrasts	No. of foci	No. of clusters	Cluster volume
Common Executive	61	573	28	40672
Common Executive minus Letter	42	446	32	26936
Common Executive minus Spatial	42	475	29	32696
Common Executive minus Arrow	43	464	34	35560
Common Executive minus Picture	40	448	26	36384
Updating minus Letter	15	172	22	14976
Updating minus Spatial	18	194	24	19344
Updating minus Picture	18	200	22	20808

Cluster volume is measured in mm^3

Contingent with these findings, first-level analyses representing activation of a particular stimuli-type reported greater cluster volume for tasks utilising letter stimuli, in comparison to those which utilised arrow, picture and spatial stimuli (Table 5 & Figure 11). Importantly, as presented in table 5, the order of activation cluster volume is not compatible to the order of the corresponding number of foci reported. E.g. the number of foci and clusters found for the picture map is greater than the arrow map, yet, the arrow map has a greater effect on the size of common executive activation. Nevertheless, to further assess the potential for bias due to the different sizes of foci between maps, foci-matched analyses were carried out. Results indicate that when foci were comparable between maps, letter stimuli still demonstrated substantially more activation than the other stimuli-types (Table 5). Of note, these analyses also revealed that picture stimuli contributed the least to executive activation, when foci were matched.

Table 5. First-level Common Executive Stimuli-type and Matched Foci Analyses

First-level Map	No. of contrasts	No. of foci	No. of clusters	Cluster volume
Common Executive	61	573	28	40672
Letter	16	127	18	13848
Arrow	11	109	13	6056
Picture	14	125	16	5664
Spatial	13	98	9	4360
Letter matched	14	98	9	9176
Arrow matched	10	99	13	5696
Picture matched	11	99	14	2896

Cluster volume is measured in mm^3

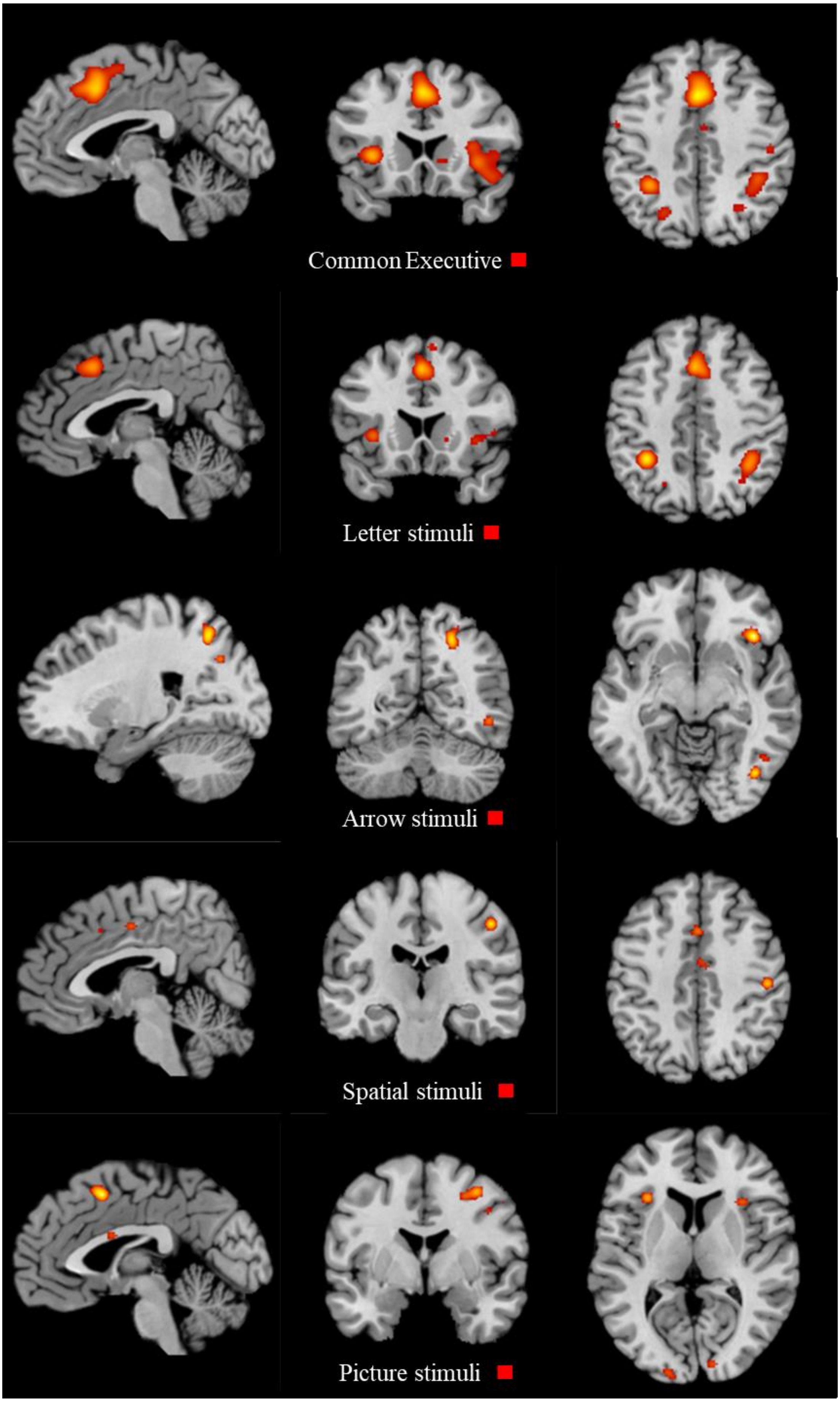
Common Executive
Letter stimuli
Arrow stimuli
Spatial stimuli
Picture stimuli

Figure 11. First-level Common Executive Stimuli-type Analyses. ALE maps depict activation relating to common executive (x= -3, y= 19, z= 42), letter stimuli (x= 1, y= 18, z= 44), arrow stimuli (x= 22, y= -60, z= 52), spatial stimuli (x= 4, y= -21, z= 42) and picture stimuli (x= -2, y= -2, z= 6).

3.3.2 Stimuli-type Second-Level Analyses

Second-level conjunction analyses were conducted for common executive compared with stimuli-type maps. Results revealed that when common executive was compared to the letter stimuli map, 16 conjunctive clusters were found. In comparison, 12 conjunctive clusters were demonstrated when common executive was compared to the arrow stimuli map, and 9 and 6 conjunctive clusters were found when common executive was compared to the spatial and picture maps respectively. Again, highlighting the differential number of foci across maps was not solely responsible for the results, as illustrated by the greater number of conjunctive clusters found for spatial stimuli, compared to picture stimuli (Table 6).

Table 6. Second-level Common Executive and Stimuli-type Analyses

Second-level Map (no. of foci in stimuli map)	No. of Conjunctive clusters found
Common Executive + Letter (127)	16
Common Executive + Arrow (109)	12
Common Executive + Spatial (98)	9
Common Executive + Picture (125)	6

3.3.3 Test-type Inhibition Analyses

First-level analyses examining the input of test-type on inhibition activity and subsequent combination comparisons between first-level analyses, as described in the methods section were carried out. The average cluster volume added from including each test in different orders (across the combinations) showed that the inhibition tests could be ranked in order of their contribution at a neural level to executive activation. The ranking order found was as follows: flanker, Stroop, go-no/go, Simon, anti-saccade, stop (Table 7).

Table 7. Inhibition Test-type Analyses.

Inhibition Task Map	Average cluster volume added	Rank
Flanker	133.66	1
Stroop	97.23	2
Go-No/Go	88.04	3
Simon	70.13	4
Anti-saccade	64.8	5
Stop	52.16	6

Cluster volume is measured in mm^3

3.4 Discussion

A meta-analysis assessing fMRI activation in children and adolescents during EF test engagement was carried out to examine activation at stimuli-type and test-type levels. ALE maps were created to assess neural activation differences between distinct modes of stimuli (i.e. picture, spatial) and inhibition tests (i.e. Stroop, anti-saccade). Results pertaining to stimuli-type analyses showed executive tests involving letter stimuli recruited the greatest proportion of common executive and updating activation. This finding was further supported by foci-matched results, which demonstrated when datasets were matched across all modalities (i.e. letter, arrow, spatial and picture), letter stimuli still contributed the most to EF activation, followed by arrow, spatial and picture stimuli respectively. Second-level conjunction analyses indicated the same pattern, with letter stimuli recruiting the largest proportion of EF activation. Additionally, inhibition data was assessed at test-type level (e.g. flanker, go-no/go, stop, anti-saccade, Simon, Stroop). These analyses resulted in ranking the inhibition tests in terms of their contribution to inhibition activation. Findings demonstrated the following ranking (beginning with the greatest contribution): flanker, Stroop, go-no/go, Simon, anti-saccade, stop.

3.4.1 Implications for the development of new EF battery

The primary aim of the study was to inform on the development of a new online EF battery to be used with children and adolescents. And in particular, determine the most appropriate task modes and test types to include in the tool, while reducing task-impurity effects. As previously mentioned, a previous pilot battery had already been created. The results suggested enhancing the use of letter stimuli in the battery. However, as outlined in the introduction, increasing language demands may negatively affect accurate EF measurement, particularly for children with reading difficulties or developmental disorders (Booth et al., 2010). Thus, in order to include letter stimuli but not place demands on language, visually presented letters that constitute cartoon characters were used as go and no-go stimuli. Additionally, letter stimuli were used in the letter-animal pairings in the letter memory task, presented pictorially as well as verbally e.g. “C for cat”. As results indicated that arrow stimuli displayed the second greatest neutral activation, arrow stimuli were utilised in the spatial updating task and Simon task.

The previous pilot battery did not contain a flanker test, yet the present findings suggest this test may have high biological validity. Further, the analyses pointed towards somewhat lower validity of anti-saccade tests. Thus, given that both flanker and anti-saccade tests involve lateral responses to directional visual stimuli, it was posited that the anti-saccade test be replaced with a flanker test (using pictures of fish instead of arrow stimuli to maintain interest and increase differences of non-executive components between tests). Additionally, as the stop task was deemed to contribute the least to executive neural activation, this test was not included in the tool. A description of the EF battery is outlined in chapter 5.

There is a clear paucity of existing research which explains why letter stimuli may be particularly effective in assessing EF. Nevertheless, in their fMRI study which compared the neural correlates of flanker task engagement with either letter or colour stimuli, Hazeltine, Bunge, Scanlon and Gabrieli (2003) found increased competition-related activation for the letter-based tasks compared to the colour-based task. This competition-related activation refers to executive activity indicative of conflict processing in incongruent trials vs neutral trials and therefore supports the present findings that suggest that letter stimuli is important to consider in EF measurement at a neural level. Additionally, the authors present an argument that suggests the greater prefrontal activity evidenced in the letter task modes correlates with the reduction in behavioural interference, indicated by slow response rate, in the executive task when this stimuli-type was utilised. Therefore, these results support the view that neural activation which represents the processing of letter stimuli overlaps considerably with executive activity. Thus, it is possible that executive tasks which incorporate letter stimuli may result in purer measurement of EF. Furthermore, Hazeltine et al. (2003) go as far to speculate that set-shifting tasks require participants to employ verbal codes, as the stimuli embedded in the tasks are not specifically associated with particular responses. Therefore, it may be plausible that the addition of verbal stimuli (with features linked to language processing i.e. letters) could facilitate this verbal code, and in turn engage executive processing demands.

In their neurocognitive model of executive control, Gruber & Goschke (2004) propose that working memory and executive control are partially mediated by a neural system which underlies language functions, including verbal rehearsal and inner speech. Further, it is postulated that this system may be responsible for the retrieval and maintenance of verbal goal representations required for switching, as in executive task engagement. They argue that switch costs can be reduced if verbal task representations are retrieved in preparation of a response, particularly in executive tasks which use arbitrary stimulus-response paradigms. Therefore, it could be argued that if executive processing, as measured by putative EF tasks, typically rely on the engagement of verbal "self-instruction" during the stimulus-response interval, it is possible that stimuli also representative of the verbal domain may recruit EF processes more directly. This model may therefore provide an explanation for the increased neural overlap between executive processing and the processing of letter stimuli.

3.4.2 Limitations

The present results examined the biological validity of stimuli modes, yet the modality of responses was not considered in this meta-analysis. Further, the new battery developed, with the assistance of this work, utilised only motor responses (e.g. pressing buttons on a keyboard and clicking with a computer mouse). Previous research suggests the modality of both stimuli and responses, as well as the compatibility between them, is important in effective assessment of EF (Stephan & Koch, 2010, 2015; Stephan et al., 2013). Therefore, perhaps examining cross-modal demands within EF tests would further elucidate effective EF measurement and in turn alleviate task-impurity. As with the previous meta-analysis, the lack of switching studies included in the data-set limits the applicability of the results to switching engagement. Accordingly, there were limits to which the findings could inform on the switching tests included in the new measurement tool. This study also did not examine activation differences between a child-only sub-sample in comparison to a child/adolescent sample, like in the previous chapter. Therefore, it cannot be determined if the impact of modality or test-type on EF measurement, and indeed executive neural activation, changes across the developmental period.

3.4.3. Summary

Overall, this study contributed to furthering our understanding fMRI activation during EF performance in children, while importantly considering the effects of modality of stimulus type and executive test type. Examining brain activation pertaining to non-executive components of EF tasks utilised by a substantial child sample is a novel and beneficial way to assess the impact of modality and test-type on EF assessment. Additionally, it provides essential insight into how to enhance pure EF measurement in children, while also taking into account specific demands presented by clinical samples. It is hoped that the new online battery of EF tests developed from this work will further elucidate accurate EF assessment and identify and examine EF deficits evidenced in children with neurodevelopmental disorders. As its development was informed by this work, it is believed this EF battery will be a valuable tool in circumventing the task impurity problem synonymous with measuring EF. Furthermore, together with the previous meta-analytic findings relating to the developmental structure of EF, as presented in the previous study, these results add to an ever-increasingly coherent and accessible picture of EF assessment in children.

Chapter 4

Identifying environmental contexts which elicit child behavioural difficulties

4.1 Introduction

4.1.1 Behaviour Problems

Behavioural dysfunction in children has a negative systemic impact on the child, their family, education and the wider community (Ogundele, 2018). Generally, in the literature, behaviour problems are divided into two categories. Externalising behaviour refers to behaviours that are directed to others or the environment, such as aggression, destruction of property, conduct problems, hyperactivity, impulsivity, non-compliance and temper outbursts (Achenbach & Edelbrock, 1978; Bask, 2015; McMahon, 1994). Whereas, internalising behaviour relates to behaviour that is directed towards oneself and corresponds to anxious, depressive and psychosomatic symptoms (Achenbach & Edelbrock, 1978; Bask, 2015; Rooney, Hassan, Kane, Roberts, & Nesa, 2013). Yet, research indicates strong comorbidity in the expression of externalising and internalising behaviour problems (Angold, Costello, & Erkanli, 1999).

Risk factors for developing behaviour problems include socio-economic status (Reiss, 2013), very preterm birth or very low birth weight (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009), as well as familial factors, such as maternal depression (Goodman et al., 2011), paternal depression and negative parenting (Rodas, Zeedyk, & Baker, 2016) and neglect (Manly, Oshri, Lynch, Herzog, & Wortel, 2013). High prevalence rates of behaviour problems have been found in atypical populations, such as those with Autism Spectrum Disorder

(ASD), Attention Deficit Hyperactivity disorder (ADHD), genetic syndromes and intellectual disability (ID) (Connor & Ford, 2012; Hill & Furniss, 2006; Matson & Shoemaker, 2009; McClintock, Hall, & Oliver, 2003; Murphy, Healy, & Leader, 2009; Niklasson, Rasmussen, Óskarsdóttir, & Gillberg, 2009). And have also been linked to later psychopathology, in adolescence and young adulthood (Cole, Peeke, & Martin, 1998; Odgers et al., 2008), as well as academic underachievement (Hinshaw, 1992) and increased criminality (Copeland, Miller-Johnson, Keeler, Angold, & Costello, 2007). Due to the high rates in stability over time (Cole et al., 1998; McMahon, 1994) and the detrimental impact on development, investigating etiological factors which may facilitate behaviour problems is of critical importance (Frick, Ray, Thornton, & Kahn, 2014; Hinshaw, 1992).

4.1.2 "Cool" and "Hot" Executive Function

Research indicates that executive function (EF) is linked to behaviour problems in development (Schoemaker, Mulder, Deković, & Matthys, 2013; White, Jarrett, & Ollendick, 2013; Young et al., 2009). Indeed, previous studies have found relationships between EF and both internalising and externalising child behaviour profiles (Kooijmans, Scheres, & Oosterlaan, 2000; Martel et al., 2007). Executive processes, specifically inhibition, switching and updating, have been implicated in the adoption and maintenance of effective behavioural regulation (Diamond, 2013; Friedman et al., 2011b). Much of the literature refers to the above EFs as examples of "cool" EFs (Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Woltering, Lishak, Hodgson, Granic, & Zelazo, 2015; Zelazo & Müller, 2002) that is, executive abilities which allow top-down cognitive processing of abstract, emotionally neutral, goal-orientated problems (Chan, Shum, Toulopoulou, & Chen, 2008; Diamond, 2013). Yet, many suggest that to solve everyday challenges, particularly those with a degree of affective conflict, both “cool” and “hot” executive abilities must be employed (Almy & Zelazo, 2015; Zelazo, 2015). Both cool and hot EFs are referred to as conscious neurocognitive processes necessary for self-regulation, but they differ on the level of motivational significance involved (Zelazo & Carlson, 2012).

“Hot” EFs are described as cognitive processes that incorporate social cognition, emotion awareness and regulation and thus support behaviours that require these components (McDonald, 2013; Zimmerman, Ownsworth, O’Donovan, Roberts, & Gullo, 2016). Therefore, hot EF skills are typically employed in response to stimuli or situations which are perceived to possess motivational or emotional content. Studies suggest that while cool EF abilities are mainly represented by activity prevalent in the dorsolateral prefrontal cortex (DLPFC) (McKenna et al., 2017; Pessoa, 2008), it is the ventromedial and orbitofrontal areas of the PFC that are associated with hot EF (Chan et al., 2008; Zimmerman et al., 2016).

The distinction between cool and hot EFs is evident in early development (Hongwanishkul et al., 2005). Perhaps this can be explained by the temporal emergence of such skills during development. It is generally accepted that early manifestations of cool executive abilities, such as inhibition, switching and updating (in the broader context of WM) are evidenced in early childhood (Garon et al., 2008; Moher & Feigenson, 2013; Pelphrey et al., 2004). Yet, cognitive emotion regulation, a self-regulatory process incorporating hot EF, is not deemed to be measurable until mid-late childhood (Garnefski, Rieffe, Jellesma, Terwogt, & Kraaij, 2007). In their study, Prencipe et al., (2011) found that when measuring cool and hot EFs in children aged between 8 and 15 years, age-related improvements in hot EF were more gradual than those pertaining to cool EF, indicating that hot EF develops at a slower rate.

4.1.3 Emotion Regulation

Emotion regulation is described as “processes used to manage and change if, when, and how (for example how intensely) one experiences emotions and emotion related motivational and physiological states, as well as how emotions are expressed behaviourally” (Eisenberg, Hofer, & Vaughan, 2007). For example, when a child (particularly a child presenting with behaviour problems) is exposed to a stressor, usually the aim is to down weight negative emotions elicited by the stressor through the use of strategies e.g. such as distracting oneself, reappraising the situation so as to minimise the negative and draw from a more positive perspective, avoidance, suppression or masking one’s feelings, using emotion or problem focused coping strategies etc. (Cisler, Olatunji, Feldner, & Forsyth, 2010).

Maladaptive ER has been linked to externalising and internalising problems such as aggression and anxiety, in children with ASD (Mazefsky & White, 2014) and depression in adolescents (Betts, Gullone, & Allen, 2009). Longitudinal evidence also suggests that emotion dysregulation in early childhood predicts later aggressive behaviour profiles in typical children (Röll, Koglin, & Petermann, 2012). In the literature, ER has consistently been connected to cool EFs in adults (Mazefsky, Pelphrey, & Dahl, 2012; Sperduti et al., 2017), yet more developmental examinations of this connection are needed (Hilt, Leitzke, & Pollak, 2014; Wante, Mezulis, Van Beveren, & Braet, 2017). Neuroscientific evidence indicates that ER relies on interactions between the prefrontal and cingulate cortices that underlie EF resources, and limbic regions, such as the amygdala and insula, known to be involved in emotional processing (Ochsner & Gross, 2008). Further, research suggests that adaptive ER processes, such as reappraisal, engage cognitive control processes (McRae et al., 2012), in particular, working memory (Schmeichel, Volokhov, & Demaree, 2008).

Crucially, previous research suggests impairment in higher-order processes such as EF may contribute to emotion dysregulation (Hendricks & Buchanan, 2016; Pechtel & Pizzagalli, 2011) and in turn, promote maladaptive processes such as rumination (Davis & Nolen-Hoeksema, 2000; Gotlib & Joormann, 2010; Joormann, Levens, & Gotlib, 2011; Whitmer & Banich, 2007). Moreover, studies have found that links between EF impairment and rumination are particularly apparent when negatively-valenced stimuli are present (Beckwé, Deroost, Koster, De Lissnyder, & De Raedt, 2013; Sperduti et al., 2017). Further efforts to understand the EF-ER relationship and psychopathology have found a mediating effect of ER (both adaptive and maladaptive) on EF deficits and depressive symptoms in adolescence (Wante et al., 2017). Interest in understanding how EF and ER are intertwined, may be due to the assumption that underlying components needed to execute effective ER, share some semblance to that of EF processing (Schmeichel & Tang, 2015; Wante et al., 2017).

Historically, research has primarily either focused on cognitive control and emotion/motivation respectively, and indeed, neuroscientific evidence has largely supported neuroanatomical distinctions between the two fields of interest (Lima, Peckham, & Johnson, 2018; Pessoa, 2008). As previously mentioned, it is widely accepted that at a neural level, top-down deliberate cognitive control, indicative of cool and hot EF, relies mainly on various regions of the PFC (McKenna et al., 2017; Pessoa, 2009). However, bottom-up processes involving emotional and motivational states occupy the subcortical limbic brain regions, such as the amygdala, ventral striatum and hypothalamus (Pessoa, 2008). It is these bottom-up automatic processing that are initially activated in response to emotionally salient stimuli (Zelazo & Carlson, 2012). Therefore, efforts to understand the necessary substrates (at both a neural and cognitive level) utilised in response to emotionally-laden goal-directed problems, have ensued.

One model which has endeavoured to bridge this gap is the Iterative Reprocessing (IR) model (Cunningham, Zelazo, Packer, & Van Bavel, 2007; Zelazo & Cunningham, 2007). The IR model is a theoretical framework by which EF is explained at multiple levels of analysis, including neural, cognitive, emotional and subjective (Almy & Zelazo, 2015). The IR model postulates that following exposure to a motivationally significant stimulus, information is repeatedly reprocessed through an interconnected neural network comprising of the thalamus, amygdala and wide-reaching areas of the PFC (Cunningham et al., 2007; Zelazo & Cunningham, 2007). Unlike other theories, the IR model suggests that information is continually shared back and forth, in real time, between regions traditionally regarded as emotional and cognitive centres respectively, during situations where adaptive behavioural responses are required. And further, this iterative flow between the thalamocortical networks continues irrespective of the stage of processing (Cunningham et al., 2007). Therefore, this model proposes that to facilitate efficient executive processing in response to real world problems, mechanisms which allow bi-directional interaction between cool and hot executive demands are employed (Almy & Zelazo, 2015; Zelazo, 2015; Zelazo & Carlson, 2012).

4.1.4 The Importance of Context

Fundamental to the Iterative Reprocessing model is the view that EF processes are utilised to regulate emotion (Zelazo & Cunningham, 2007). And that this regulatory processing is achieved through the amplification or dampening of attention directed towards particular events which occur in the environment, or 'contexts' as we refer to it here, which are deemed to be emotionally salient or aversive. It is this continual reweighting of attention towards/away from features of stimuli/contexts, supported by connections between the lateral PFC and the thalamus, which underlies the "emotion regulation as EF model". And indeed, when contexts are perceived as particularly aversive, reprocessing involved in regulation may be weakened (Mazefsky et al., 2012; Zelazo & Cunningham, 2007). Nevertheless, during typical development, improvements in reprocessing, even in the face of emotionally salient contexts, are assumed to be facilitated by continued development in prefrontal networking. Agreeing with this suggestion, Mazefsky et al. (2012) proposes that disruption to reprocessing (as illustrated in this model) may provide an explanation for regulatory deficits evidenced in individuals believed to possess underdeveloped prefrontal connectivity capacities, such as in ASD, when exposed to emotionally salient contexts. Therefore, it has been argued that the IR model provides a strong basis for considering the negative effect of emotional salience on EF, and consequently ER (Mazefsky et al., 2012; Zelazo & Cunningham, 2007).

Further evidence provides support for the deleterious impact of affective interference on EF and ER. Specifically *highly negative* stimuli can undermine the ability to engage in executive control (Evans & Rothbart, 2009; Pessoa, 2009), and indeed, highly negative stimuli are intrinsically linked to the context in which they occur. Additional findings suggest that exposure to emotionally salient contexts which deplete effective regulatory resources may be explained by increased and prolonged activity of the amygdala, as well as reduced functional connectivity between the PFC and the amygdala (Wagner & Heatherton, 2013). Further, increased reactivity in the amygdala in response to such contexts, may arise due to impaired inhibition of this structure by the DLPFC (Siegle, Steinhauer, Thase, Stenger, & Carter, 2002) also adding support for the PFC-limbic interaction in such situations.

The importance of context processing is further demonstrated by the Social Context Network Model (SCNM) (Baez, Garcia, & Ibanez, 2016). This model emphasises the role of context in social cognitive processing, mediated by a fronto-temporo-insular network (Ibañez & Manes, 2012). Importantly, the SCNM suggests impairments in the neural networks, which underpin the integration of contextual information with ongoing goals, across a number of neurodevelopmental disorders linked to behaviour problems. The networks in question overlap considerably with those involved in executive processing and the authors claim there is still an open question regarding the role of general EF deficits in the expression of these more specific context integration deficits.

As the most successful approach for intervening with challenging behaviour, Applied Behaviour Analysis (ABA) suggests that considering everyday situations is of utmost importance to achieving behavioural change (Carr & Durand, 1985; Hanley, Iwata, & McCord, 2003). ABA-based intervention work is grounded in evidence demonstrating that behavioural change can be achieved if the environment is manipulated in such a way that reinforcing contingencies for behaviour are altered so as to favour the desired behaviour. For this reason, identifying antecedent "triggers" and reinforcing consequences for behaviour problems in individuals, is of paramount importance in developing effective individualised treatment (Doehring, Reichow, Palka, Phillips, & Hagopian, 2014; Hagopian, Rooker, Jessel, & DeLeon, 2013; Hanley et al., 2003). However, consideration of contextual interference on the cognitive processes that allow a person to control their behaviour is also needed. Indeed, Woodcock, Oliver, & Humphreys (2011) identified a link between an EF deficit, specifically switching, and temper outbursts in children with Prader-Willi syndrome when a change to routine occurred. The relationship between cognitive impairment and behaviour identified in this research was explained by the impact that the context (here, a change in expectation) had on a child's executive control ability. Therefore, considering the established evidence (through behavioural intervention work) that emphasises the role of context in behaviour problems, as well as the emerging evidence suggesting the impact of context on EF and ER, consolidation of these components is needed to provide a greater understanding of the "context-EF/ER-behaviour" picture.

4.1.5 Contexts Across Diagnoses

As previously discussed in section 1.5, the Research Domain Criteria (RDoC) project was initiated in response to the high proportion of comorbidities and overlapping collections of symptoms evidenced across multiple disorders (Caspi et al., 2014;

Cuthbert & Insel, 2013). Therefore, the RDoC promotes examining neurobiological markers that reflect cognitive and behavioural dysfunction across traditional diagnostic groups in an effort to provide better insight into clinical impairment and therefore, influence informed intervention (Etkin & Cuthbert, 2014; Krumholz Marchette & Weisz, 2017).

A "transdiagnostic" perspective complements the RDoC project, as it aims to identify transdiagnostic factors that may underlie difficulties exhibited across different disorders (Fernandez, Jazaieri, & Gross, 2016). Indeed, evidence suggests overlapping deficits in numerous domains exist across disorders (Clark & Watson, 1991; McEvoy, Watson, Watkins, & Nathan, 2013) and some of these deficits are reflective of intolerance to a specific context(s) (Gentes & Ruscio, 2011). One such difficulty is a *resistance to change*. Research indicates that exposure to an unpredicted change in the environment is highly aversive for individuals across many diagnostic populations (Furniss & Biswas, 2012; Lidstone et al., 2014; Tunnicliffe, Woodcock, Bull, Oliver, & Penhallow, 2014; Woodcock, Oliver, & Humphreys, 2009; Zaboski & Storch, 2018). Importantly, this resistance to change has been explained as a manifestation of impairment in EF (Wilding, Cornish, & Munir, 2002; Woodcock et al., 2011), and EF deficits present across several of the same disorders (Goodkind et al., 2015, Kofler et al., 2018; Lima et al., 2018; Snyder, Miyake, & Hankin, 2015). Further to EF, transdiagnostic proponents have suggested that ER should also be considered a transdiagnostic factor (Aldao, 2016; Fernandez et al., 2016). Therefore, relationships between context, EF and ER appear to cross diagnostic boundaries and so when examining these relationships, a transdiagnostic approach is important.

4.1.6 The present study

The aim of the present study was to identify emotionally salient contexts which may potentially impact EF and ER, and thus, group children in terms of the disabling impact of their internalising/externalising behaviour exhibited in these contexts. Moreover, as evidence suggests these EF and ER may be treated as transdiagnostic factors, children across the transdiagnostic spectrum were examined in the present study. In addition to including children with differential diagnoses, children with no diagnoses also participated. Ultimately, we hoped that group categorisation will allow us to identify specific profiles of deficit in EF and ER processes that predict membership in each of these contextually specified behavioural groups. We aimed to examine these profiles with a view to generating hypotheses for future work about exactly *how* emotionally salient contexts may impact on children's control processes such that such relationships can be examined in future work.

4.2 Methods

4.2.1 Design

The aim of the present study was to identify contexts or situations which may be perceived as emotionally salient to children and therefore, result in maladaptive behavioural and/or emotional responses. By these means, we hoped that the exploration of these situations would aid us in identifying specific components of contexts which may be clinically meaningful. And moreover, provide further insight into how the emotional salience of such situations may undermine control processing (EF and ER), which in turn, generates behavioural and emotional dysfunction.

Prior to study commencement, a variety of sources were searched to identify contexts which are linked to behaviour problems. Information retrieved subsequently informed on the contexts investigated, and how they should be presented in a measure of how such contexts impact on children's behaviour problems and emotional functioning (context measure). This information is described in the "Development of the context measure" section.

The four contexts of interest were as follows:

Perceived criticism: *e.g. when others make negative comments about him/her or when others tease or ridicule him/her*

Disappointment: *e.g. when he/she receives a less preferred outcome than he/she was hoping for, i.e. when their sports team loses or when they cannot have something that they want or cannot continue with a preferred activity.*

Perceived failure: e.g. *when he/she can't achieve a goal or make errors in their work or can't complete a task to the best of their ability.*

Perceived unfairness: *e.g. after feeling that he/she is being treated unfairly e.g. when something is being shared out and he/she receives less than someone else.*

Following the identification of the contexts of interest, during the development phase of the context measure, the tool was piloted with parents, academic staff and clinicians. These individuals provided feedback on the applicability of the content included in the measure, and the accessibility and usability of the measure itself. Findings from these pilots subsequently informed amendments of the tool and some other components to the design of the study. A pilot study was implemented with 8 parents and 8 children before a final version of the measure was developed and utilised with remaining participants. Following the pilot study, we reviewed the effectiveness of the main assessment tool, which subsequently led to further changes to the measure- effectively reducing participant demands and streamlining the overall testing procedure.

The tool was administered to parents in a semi-structured interview fashion and answers pertaining to the quantitative aspects of the measure were recorded, using the measure as a visual tool on a laptop. More information relating to the administration is detailed in the procedure section.

4.2.2 Participants

63 parents and 63 children, aged between 6 years and 12 years (or up to 16 years if they had an intellectual disability), participated in the study. Eight children and parents who took part in the pilot were also included in the sample, as all relevant data for the analyses was obtained from them. Emotional and/or behavioural difficulties were an inclusion criterion but specific diagnosis was not, therefore children with and without diagnoses participated in the study. Demographic information relating to age, gender, IQ, diagnostic status is presented in Table 8.

Table 8. *Demographics of sample (n=63)*

	Mean (SD) (years)
Age	9.56 (2.80)
	%
Gender	63% Male
Diagnostic status	66.6% with diagnosis (n=42/63)
ASD (with or without comorbid diagnoses)	24
Genetic Disorders (DS, FASD, Neurofib)	9
ADHD (with no comorbidity)	4
Intellectual Disability	5

ASD= Autism Spectrum Disorder, DS= Downs Syndrome, FASD= Foetal Alcohol Spectrum Disorder, Neurofib= Neurofibromatosis (type 1), ADHD= Attention Deficit Hyperactivity Disorder, SD= Standard Deviation

N.B. 3 participants included in the "No diagnosis" group presented with learning difficulties, specifically, dyslexia, dyspraxia and dyscalculia.

4.2.3 Development of the context measure

As previously mentioned, a parent-report assessment tool was developed by the researchers to examine contexts which most elicit clinically relevant behaviour or emotional responses. This tool was designed to allow the acquisition of in-depth information about the contexts of interest, i.e. parents were asked to think about their child's behaviour in a number of specific contexts, and then answered closed and open-ended questions about their behaviour in each.

The following section will provide more detail about how each of the contexts were informed, as well as an explanation for the terminology used in the measure. In order to operationalize the contexts, one area we drew from was the emotional task paradigm literature. Emotional task paradigms aim to evoke an emotional state in response to a putative stimulus. Usually studies which incorporate such tasks aim to measure how this emotional response impacts on other processing or constructs, such as cognitive control or theory of mind, for example (Megías, Gutiérrez-Cobo, Gómez-Leal, Cabello, & Fernández-Berrocal, 2017; Mizokawa & Koyasu, 2013; Schug, Takagishi, Benech, & Okada, 2016). Another objective for utilising emotional paradigms is to assess behavioural responses to experimental situations which induce emotional responses, such as disappointment or unfairness (He et al., 2013; Takagishi et al., 2014; Wu, Feng, Hooper, & Ku, 2017). Therefore, literature employing emotional tasks was relevant to our examination of contexts which elicit behavioural responses. In addition, behavioural descriptions and information on antecedent events resulting in challenging behaviour, provided in interviews from published (Tunnicliffe et al., 2014) and unpublished sources also informed on the operationalisation of the contexts e.g. parental interviews from ongoing work carried out by our research team.

When considering possible contexts of interest, it was ascertained that firstly, contexts must be situations that have the capacity to evoke emotional and behavioural responses. They must be situations which have been found to regularly occur in children’s daily lives. And finally, they must not be contexts which are associated with one particular diagnostic presentation- e.g. there is evidence to suggest intolerance of uncertainty is a particular deficit of children with ASD. It was expected that the identified contexts would not differentiate children in terms of their behaviour profile, as it was anticipated a wide array of behaviours would be shown across the contexts. Nevertheless, it was hoped discussing specific examples of clinically relevant situations that relate to these identified contexts, would provide rich insight into important underlying components that dictate designation into clinically relevant contextual groups. Furthermore, to ensure responses were not confounded by the presentation of contexts already identified by researchers as potentially clinically relevant, the tool incorporated an additional "other" option. This option afforded parents the opportunity to describe a situation which they deem to be more negatively impacting for their child other than the contexts already presented. The inclusion of an "other" context ensured the contextual information received was truly representative and clinically meaningful for parents, and also reduced the potential for directing responses in a preconceived way.

4.2.3.1 Contexts of Interest

4.2.3.1.1 Disappointment

Description used in measure: "as a result of a disappointment, e.g. when they receive a less preferred outcome than they were hoping for, i.e. when their sports team loses or when they cannot have something that they want or cannot continue with a preferred activity."

Literature pertaining to the disappointment paradigm served as a source of reference when examining this context of interest. The disappointment paradigm is an observational technique used to elicit externalising behaviour in preschool (Cole, Zahn-Waxler, & Smith, 1994; Feng et al., 2008; Garner & Power, 1996) and school-aged children (Bohnert, Crnic, & Lim, 2003; Garrett-Peters & Fox, 2007). The disappointment paradigm involves children ranking objects in terms of their desirability, they are then told they will receive one of the items as a prize (usually as a result of completing a task), following this, children are given the least desirable object as a prize. Therefore, facets of this situation were included in the description of the disappointment context in our questionnaire (see above).

In their study, Tunnicliffe et al. (2014) investigated the expression of temper outbursts in children and adults with Prader-Willi syndrome (PWS) and environmental factors associated with this behaviour, through semi-structured interviews with caregivers. Tunnicliffe et al. (2014) described the following as antecedent events which led to temper outbursts in their sample- “cannot have something that they want” and “interruption of preferred activity”. Therefore, these examples were incorporated into the disappointment description as presented in the measure.

4.2.3.1.2 Unfairness

*Description used in measure: “*after feeling that he/she is being treated unfairly, e.g. when something is being shared out and he/she receives less than someone else.”

The Unfair Card Game (UCG) is a new tool to assess externalising behaviour in preschool children (Roskam, Stievenart, Brassart, Houssa, Loop, Mouton et al., 2016). In this game, the child receives fewer rewards than a virtual player, despite good performance of the task. It could be argued that the definition of the context in our measure (see above) complements that of the components of the UCG and other economic games. The UCG has been used and validated through factor analyses, reliability analyses, discriminant analyses, test-retest and inter-rater reliability checks in children aged 3 to 6 years (Roskam et al., 2016). Results from this study were also externally validated with the aggressive behaviour and attention scales (part of the second-order externalising behaviour scale) in the Child Behaviour Checklist (CBCL) (Achenbach & Rescorla, 2004). Although this measure is intended for use in very young children, as the theoretical perspectives presented previously suggest that the emotional salience of such situations may continue to be particularly challenging for some individuals, it was ascertained that this context could still act as an appropriate context of interest for the current sample.

Examples of unfair situations which elicited maladaptive behaviour responses were also retrieved from parental interviews carried out by our research team. One such example from this data which depicted perceived unfairness was as follows, 'when brother gets an extra strawberry or sister gets an extra push on the swing'.

4.2.3.1.3 Criticism

Description used in measure: "e.g. when others make negative comments about him/her, or when others tease or ridicule him/her."

Upon review of the literature, it became apparent that the contexts of 'being criticised' and 'perceived failure' have not been systematically described. Therefore, examples provided through interview informed the descriptions of these contexts in our measure.

Tunnicliffe et al. (2014) identified when a child is 'teased' as an antecedent event which resulted in a temper outburst for individuals from her sample. In addition to being teased alternative descriptions were presented through interview in our ongoing work. Examples include, 'being joked about', 'made fun of by peers', 'when others don't want to play with them' (believing this is a fault of their own)', 'or even when friends are not at home so she can't play with them…she perceives that as them not wanting to play with her', 'teachers telling them off'.

4.2.3.1.4 Failure

Description used in measure: "when they can't achieve a goal, make errors in their work or can't complete a task to the best of their ability."

The inclusion of 'making an error in their work' in the above contextual description was informed by previous findings in Tunnicliffe et al. (2014) where this situation was presented as a trigger for subsequent outbursts. Other examples of perceived failure evidenced in our interview data were as follows, *'Imperfection, not doing something as well as he would like to'*, *'When playing computer games if there's something he can't do and gets stuck or can't finish games, he gets cross with himself', 'lost in a game/sport'.* Therefore, efforts to encapsulate these examples into the context description in the current measure were made.

4.2.3.2 Assessment of associated behaviour, emotion and its impact

As well as gaining detailed contextual information, this tool afforded us to retrieve information regarding the profile of the behaviour presented following the context deemed the most negatively impacting, the clinical impact of the behaviour, the emotional salience of the context, and how caregivers typically respond to this behaviour (however it must be noted that data pertaining to parenting response will not be discussed in this thesis). To achieve this, different facets of previously validated measures were included in the questionnaire, and in some cases, amended.

4.2.3.2.1 Previously validated measures modified for use in the context measure

4.2.3.2.1.1 Child Behaviour Checklist (CBCL) (Achenbach, 1991)

The Child Behaviour Checklist (CBCL) (Achenbach, 1991) is a very widely used and validated measure, used to assess behavioural, emotional and social problems in children aged 6 – 18 years. This measure has been used and validated in many studies investigating children with neurodevelopmental disorders and psychiatric conditions, particularly in the examination of diagnostic status and impairment (Bilenberg, 1999; Ivarsson & Larsson, 2008; Yang, Soong, Chiang, & Chen, 2000). Bilenberg (1999) found good construct validity (via factor analysis) and acceptable inter-parent reliability ($r = 0.65$) and test-retest reliability ($r = 0.85$) in Danish referred- and population-based samples. Ivarsson & Larsson (2008) reported good discriminative validity of items indicative of obsessive compulsive symptoms in clinical samples consisting of children referred to a specialised Obsessive Compulsive Disorder (OCD) clinic, and children referred to regular outpatient child psychiatric clinics. These samples were then compared to a normative school-based sample. Yang et al. (2000) found good internal consistency and test-retest reliability (all α values and reliabilities >0.6, in all but the thought problems scale) in a Chinese version of the measure, utilised with a non-referred Taiwanese adolescent sample.

4.2.3.2.1.2 Challenging Behaviour Interview (CBI) (Oliver, McClintock, Hall, Smith, Dagnan & Stenfert-Kroese, 2003)

The Challenging Behaviour Interview (CBI) is an assessment tool for determining the severity of challenging behaviour. It has been used and validated in children (aged 4 to 12 years) and adults (aged 17 to 58 years) who presented with intellectual disabilities and challenging behaviour. Analyses indicated adequate mean inter-rater reliability (part 1 of interview- $\kappa = 0.67$, part 2 of interview- $r= 0.48$) and mean test-retest reliability (part 1- $\kappa = 0.86$, part 2- $r= 0.76$). Concurrent validity with the Aberrant Behaviour Checklist (ABC) (Aman, Singh, Stewart, & Field, 1985) ranged between $r=0.19$ - 0.68 and content validity was demonstrated by significant differences in the clinical impact of the behaviours shown, and the variability in severity of the different behaviours.

4.2.3.2.1.3 The Self-injury, Aggression and Destruction Screening Questionnaire (SAD-SQ) (Davies & Oliver, 2016)

The Self-injury, Aggression and Destruction Screening Questionnaire (SAD-SQ) (Davies & Oliver, 2016) is a brief screening tool in which a selection of items from published measures is combined to identify whether an individual is at high/low risk of exhibiting challenging behaviour. The authors report good reliability (with inter-rater reliability ranging from .21 to .47), and good concurrent and convergent validity (see Davies & Oliver (2016) for specific validity scores).

4.2.3.2.1.4 Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997)

The SDQ is a self-report or informant-report questionnaire which assesses children and adolescent’s positive and negative attributes. 25 items indicate scores on 5 subscales, measuring for conduct problems, hyperactivity-inattention, emotional problems, peer problems and prosocial behaviour. An additional impact supplement assesses whether the individual in question has problems which indicate a clinical need, in relation to the chronicity of the problem, the distress associated with the problem, if it results in social impairment or creates a sense of burden (Goodman, 1999). This measure has been used recently with children aged 11-19 years who avail of Child and Adolescent Mental Health Services (CAMHS) - some of whom have diagnoses of neurodevelopmental disorders and mood disorders, (Hall et al., 2015) and has previously been validated in a large sample of typically developing children and children receiving psychiatric support, aged 5-15 years (Goodman, 1999). The impact scales showed good discriminant validity, with burden rating on the measure correlating strongly with a standardised interview rating of burden (r= 0.74).

4.2.3.2.1.5 Self-Assessment Mannequin (SAM) (Bradley & Lang, 1994)

The SAM is a self-report non-verbal pictorial technique which allows participants to rate their emotion in response to different stimuli, using scales that measure levels of pleasure/valence, arousal and dominance. The SAM has been used with different adult populations across the lifespan and cross-culturally (Fairfield, Ambrosini, Mammarella, & Montefinese, 2017; Huang et al., 2015; Picou, 2016). Large agreement has been demonstrated across these samples, particularly for the valence scale (Fairfield et al., 2017).

4.2.3.2.1.6 Cognitive Emotion Regulation Questionnaire (CERQ) (Garnefski, Kraaij, & Spinhoven, 2001)

The CERQ measures 9 cognitive ER strategies associated with experience of negative life events. The CERQ strategies are: Refocus on planning (positive strategy), rumination (negative strategy), putting into perspective (positive strategy), catastrophising (negative strategy), positive refocusing (positive strategy), positive reappraisal (positive strategy), acceptance (positive strategy), self-blame (negative strategy), and blaming others (negative strategy). Analyses by Garnefski et al. (2007) suggest good factorial validity, including sufficient content and criterion-based validity, and high reliabilities with Cronbach's alphas ranging between 0.75 – 0.87. Results show strategy usage relates to measures on the Childhood Depression Inventory (CDI) (Garnefski et al., 2007) and the Positive and Negative Affect Scale (PANAS) (Domínguez-Sánchez, Lasa-Aristu, Amor, & Holgado-Tello, 2011). The measure has been used with children with separation anxiety disorder (SAD), aged 9 to 13 years old (Afshari, Neshat-Doost, Maracy, Ahmady, & Amiri, 2014). Further, the measure has been recently validated in a typically developing Chinese sample aged 9 to 11 years (Liu, Chen, & Blue, 2016).

4.2.3.2.2 Modification of measures

Many of the previously validated tools (presented above) utilised in the context measure were modified to reduce the participant demands, in terms of the amount of time taken to complete this measure, bearing in mind the other task engagement required for study participation. Therefore, in some cases the measures were shortened by omitting some items or scales. Other modifications included changing the wording typically used in the measures, in order to examine, for example, the behaviour/emotional responses or emotion ratings pertaining to the contexts of interest. Therefore, adaptations to the language afforded more specific information about responses, in relation to the context in question, to be obtained.

4.2.4 Description of the context measure

Firstly, the context measure aimed to identify the context that parents deemed to be the most negatively impacting on the child. The content displayed at the beginning of the measure was as follows, "*We would like you to think about any difficulties you child shows with their behaviour in the following scenarios:*" Before presenting the 4 contexts of interest descriptions, as previously shown in section 4.3.2.1. The descriptions were then followed by, "*Please tell us which one of the below scenarios has the biggest negative impact on your child's life.*" The four contexts were then displayed again, with an additional option- "*Another situation (please describe)*" and participants were requested to select an option by clicking the mouse on the relevant 'bubble' on screen.

*4.2.4.1 Behavioural Profile (*informed mainly by the *Child Behaviour Checklist (CBCL)* (Achenbach, 1991)

The next section presented in the context measure pertained to the behaviours shown by children in response to experiencing the context identified by their parents as the most negatively impacting. Participants were asked "*When this situation occurs, does he/she show behaviour that is: (if applicable, please tick)*" and were presented with a list of 13 behavioural descriptors (as demonstrated in table 9), e.g. "*Insecure (e.g. clingy, feels or complains no one loves him/her, feels worthless or inferior, self-conscious or easily embarrassed)*". Participants were requested to select any of the behaviours that were applicable by 'ticking the relevant box' using their mouse. In addition to these 13 behaviours, there were also two further options participants could select "*Other (please describe)*" and "*None of the above*".

Behavioural descriptors were taken from the Child Behaviour Checklist (CBCL) (Achenbach, 1991), the Challenging Behaviour Interview (Oliver et al., 2003), the Self-injury, Aggression and Destruction Screening Questionnaire (SAD-SQ) (Davies & Oliver, 2016) and other published sources (see table 9).

Table 9. Definitions of behaviours presented in the current measure and their corresponding sources.

Behaviour	**Definition**	**Source**
Aggressive	e.g. punching, pushing, kicking, pulling hair, grabbing other's clothing etc.	SAD-SQ
Withdrawn	e.g. doesn't get involved with others, refuses to talk, keeps things to self	CBCL
Unhappy	e.g. cries a lot, complains of loneliness	CBCL
Self-injury	an action towards the self (e.g. hitting, biting) that has the potential to cause harm and can result in tissue damage	Challenging Behaviour Interview (Oliver et al., 2003)
Destructive	throwing or stamping on objects which can result in damage to the objects	Challenging Behaviour Interview (Oliver et al., 2003)
Temper Outbursts	e.g. a sudden/explosive episode of behaviours that may include arguing, shouting, screaming, facial flushing, stamping, angry facial expression, 'storming off', destruction and/or aggression	(Potegal, Kosorok, & Davidson, 2003)
Non-compliant	failing to follow or doing the opposite of an instruction, directive, or request	(Owen, Slep, & Heyman, 2012)
Thought Problems	e.g. worries a lot, can't get his/her mind off certain thoughts	CBCL

Fearful	e.g. fears going to school, fears certain animals, situations or places, fears he/she might think or do something bad	CBCL
Irritable	e.g. stubborn, sullen, sulks a lot	CBCL
Nervous	e.g. highly strung, tense, shows nervous movements or twitching	CBCL
Somatic complaints	e.g. complains of physical problems without known medical cause	CBCL
Insecure	e.g. clingy, feels or complains no one loves him/her, feels worthless or inferior, self-conscious or easily embarrassed	CBCL

4.2.4.2 Impact scales of the Strengths and Difficulties Questionnaire

(Goodman, 1997)

The following section of the measure aimed to assess the clinical impact of the contexts on the child's behaviour. Specifically, the items used were to investigate the overall distress, social impairment, chronicity and burden of the contextual behaviour exhibited. The first item was presented as follows, "*Overall, how would you rate the difficulties your child has in this situation?*" *{'difficulty item'}*. Participants were required to select a response which indicated either "*No difficulties, Yes- minor difficulties, Yes- definite difficulties, Yes- severe difficulties*". It was anticipated that further questioning would cease if parents selected "*No difficulties*", however this did not occur. If parents selected one of the other 3 responses, the following questions and responses were presented, "*If you answered 'Yes,' please answer the following questions about these difficulties.* 1. *How long have these difficulties been present? [Less than a month, 1-5 months, 6-12 months, Over a year]* 2. *Do these difficulties upset or distress your child? {'distress item'} [Not at all, Only a little, Quite a lot, A great deal]* 3. *Do these difficulties interfere with your child's everyday life in the following areas? Home life? Friendships? Classroom learning? Leisure activities? {'social impairment items'} [Not at all, Only a little, Quite a lot, A great deal]* 4. *Do the difficulties put a burden on you or the family as a whole? {'burden item'} [Not at all, Only a little, Quite a lot, A great deal]*." The context measure is presented in Appendix L.

Only the impact scales of the SDQ (Goodman, 1999) were used in the context measure, to assess the impact of behaviour difficulties, expressed within our contexts of interest, on everyday life. The impact scores can be classified into 3 bands of functioning: the normal range (a score of 0), the borderline range (a score of 1), the abnormal range (a score of 2 or more). The impact supplement of the SDQ has been linked to clinically relevant impairment via association with diagnostic status and association with clinical improvement (Goodman, 1999; Goodman, Ford, Simmons, Gatward, & Meltzer, 2003; Mathai, Anderson, & Bourne, 2003).

4.2.4.3 Open-ended Context Questions

As previously discussed this tool was developed to gain in-depth information about emotionally salient contexts, therefore the tool utilised open-ended questioning. The responses to these questions were then used to inform the contextually-specified groupings. The first open-ended question was asked when the parents identified the context that was negatively impacting for their child. It was presented as follows, "*Please describe a situation in which your child has shown difficulties with their behaviour after* [insert relevant context of interest *i.e. feeling criticised/a perceived failure/a disappointment/being treated unfairly*]." A further open-ended question was asked which related to the parent's response to the behaviour ("*When your child shows these difficulties with their behaviour when they [insert context], how do you typically respond?*"). Again, the information pertaining to parental responses allowed researchers to acquire rich and detailed data, which was then coded through thematic analysis. However, as discussed previously, the consideration of this work is beyond the scope of this thesis.

4.2.4.4 ***Self-Assessment Mannequin (SAM)*** (Bradley & Lang, 1994)

Parents were given the option to discontinue testing at this point of measure (see appendix L) in order to alleviate participant demands. However, all participants chose to continue. The emotional salience of the context identified as the most negatively impacting for the child was assessed in this section. This was achieved by utilising the valence, dominance and arousal scales of the Self-Assessment Mannequin (SAM) (Bradley & Lang, 1994). As the SAM was used in reference to the contexts of interest, some wording was changed to incorporate details of the context previously described by the parent, "*Please indicate how happy or unhappy your child felt in this situation* [valence], *Please indicate how calm or excited/jittery/nervous your child felt in this situation* [arousal], *Please indicate how big or small your child felt in this situation* [dominance]". Each of these items used a pictorial scale (see appendix L) that depicts a range of emotional responses. Participants were able to select between 1-9 on the scale or they could select an additional "*I can't tell*" option. Researchers also used an amended version (to incorporate the contexts of interest) of the SAM script (see appendix M). This script was utilised to enhance participants' understanding of the questions being asked, by providing a more complete explanation of how to interpret the SAM scales.

Additionally, it is important to note this tool was utilised as a parent-report, instead of self-report. As the study required parents to report on occurrences of emotionally salient contexts, it was felt it would be more appropriate to ask them to complete the emotional salience measure. Furthermore, the SAM was also utilised by children as a self-report in the pilot study, however, it was felt the children were too confounded by social desirability- so much so that some did not indicate that they found the contexts in question to be aversive at all, or would not admit the occurrence of such events. Therefore, it was determined the child responses were not valid and thus, the analyses only utilised parent-report ratings.

4.2.4.5 Cognitive Emotion Regulation Questionnaire (CERQ) (Garnefski et al., 2001)

The next section of the measure examined the emotion regulation (ER) strategy usage of the children, by asking parents to rate how much their child uses different ER strategies during the contexts of interest. 9 items were presented and participants were asked to select from one of the following responses, "*(Almost) Never, Occasionally, Sometimes, A lot, (Almost) Always*". These responses were ranged from 1 to 5, with a selection of *(Almost) Never* constituting a score of 1 and a selection of *(Almost) Always* constituting a score of 5. The instruction for this section was displayed as follows, "*Sometimes children show how they feel about a situation* *through their behaviour and/or in what they say. We would like to know how your child typically responds to the situation you have described. Please indicate how often they show these responses. If you feel like you can't tell how your child is feeling in this situation, please tell the researcher.* The 9 items were as follows, 1. "*They think that basically the cause must lie within themselves*", 2. "*They think they have to accept that this has happened"*, 3. "*They are preoccupied with what they think and feel about what they have experienced*", 4. "*They think of pleasant things that have nothing to do with it*", 5. "*They think about a plan of what they can do best*", 6. "*They look for the positive sides to the matter*", 7. "*They think other people go through much worse experiences*", 8. "*They think that what they have experienced is the worst that can happen to a person*", 9. "*They feel that basically the cause lies with others*".

We utilised the Cognitive Emotion Regulation Questionnaire (CERQ) (Garnefski et al., 2001). There is a child self-report version of the CERQ (the CERQ-Kids version (CERQ-K)) which is intended for use by children aged 9-11 years. Because many of the current sample are younger than this, the CERQ was instead used as a parent-report measure. We altered the tool by reducing the number of questions, using one item only per strategy so as to reduce participant demands. This was determined by previous factor structure results (Garnefski & Kraaij, 2007) in which factor loadings were presented for each item utilised at two time-points. Items with the highest average loadings across both time-points were selected to be included in the current measure.

4.2.4.6 Ranking and exploration of other contexts

The last section of the context measure required participants to rank the contexts in order of how negatively impacting they are for their child. The content was presented as follows, "*Thank you for telling us about the scenario which has the biggest negative impact on your child's life. Thinking back to the other scenarios (displayed below):* [The descriptions of the contexts were presented, as previously] *Please rank the below scenarios in terms of the negative impact they have on your child's life. You can do this by dragging and dropping the options into the correct position. Number 1 should be the scenario you have previously described, in other words the scenario you think has the biggest negative impact on your child's life, and number 5 should be the scenario you feel has the least negative impact. If you do not have an example for the 'other situation' option, please rank this as number 5.*"

Each context was then assessed using the SDQ impact items as demonstrated in section 4.2.4.2. However, for these contexts, the items were reduced, and thus only the 'difficulty', 'distress' and 'burden' items were utilised. Therefore, in order to ascertain the clinical impact score across contexts, these items, as opposed to the 'social impairment items' (which is typical) were used (see section 4.2.4.2 for item wording). This modification was primarily to reduce participant demands. An example of the instructions for this section were as follows, "*Please answer the following questions regarding the scenario you have selected as number 2 (the second biggest negatively impacting situation).*"

4.2.5 Procedure

Ethical approval was obtained from the School of Psychology ethics board at Queen’s University, Belfast and informed consent and assent were retrieved from all adult and child participants respectively, before taking part in the study. Participants were recruited through schools, support organisations, Queen’s University Belfast and via social media. Demographic information was sought, including information regarding diagnosis and medication. Face-to-face interviews with parents were conducted at their homes, in the University or at their child’s school. All interviews were audio recorded for coding purposes. Two parents completed the interview over the telephone, which were also audio recorded. Descriptive accounts of contexts of interest were obtained from parents via a semi-structured interview, while information pertaining to closed questions/quantitative data were inputted in real time, through the context measure, which was presented as a visual tool on a laptop (see Appendix L). This measure also acted as a screening tool, e.g. if parents did not rate the contexts as resulting in clinical levels of behaviour and/or emotional difficulties in their child, as measured by the impact supplement of the SDQ, they were deemed not suitable to take part in the study. In other words, if respondents did not select ‘Yes- definite difficulties’ or ‘Yes- severe difficulties’ on the item, ‘Overall, do you think that your child has difficulties with their behaviour when...’ for a specific context, they were not asked any more questions (however, no participants were excluded in this way).

Following the administration of the context measure, parents were requested to complete the 25-item symptom scale of the SDQ, the Dysexecutive Questionnaire (DEX) (Burgess, Alderman, Wilson, Evans, & Emslie, 1996) and the Parenting Scale

(Arnold, O'Leary, Wolff, & Acker, 1993). Following this, children completed an online battery of EF tests and the Similarities and Digit Span subtests of the Wechsler Intelligence Scales for Children (WISC-IV) (Wechsler et al., 2003). These measures are described in full in Chapter 5.

4.2.6 Scoring, Coding and Reliability

Internalising and externalising behaviour profile scores were calculated from the responses in the behavioural description section. The number of different types of internalising and externalising behaviours displayed by children were added and formed behaviour profile scores. The internalising and externalising profile scores were then used to create a behavioural group variable which classified children into 3 further groups, that is, children who only exhibited internalising behaviour, children who only exhibited externalising behaviour, and children who exhibited both internalising and externalising behaviour.

Prior to the analysis of the data, the theoretical position argued there may be something inherently important within the contexts themselves or the children's' perception of the contexts, which warrants examination and which has the potential to inform the differentiation of children into functional groups. Therefore, it was ascertained that the identification of latent themes be explored, which portray underlying conceptualisations about the contexts in question and in turn, may impact maladaptive behavioural and/or emotional responses. In the current study, the latent approach commenced as early as data collection when the researcher noted potential latent themes within the data which may support meaningful classification. However, these analytic interests were not considered in depth until all data was collected, the transcription of interview responses was completed and repeated reading of the data was pursued. Contextual information provided by parents was further examined until the final themes were acknowledged and reviewed through the creation of detailed thematic descriptions (details of the themes and thematic descriptions are discussed in the results section). The descriptions of the themes were then utilised to allocate children into groups based on the qualitative contextual descriptions of the emotionally salient situations provided by parents. An independent rater also reviewed all interview data and categorised responses to the assigned themes. Inter-rater reliability was calculated through agreement of the categorisation between the two researchers.

4.3 Results

The aim of the present study was to utilise the four chosen contexts to gain clinically meaningful information about emotionally salient situations which may warrant further investigation. Researchers conducted a systematic analysis of the open-ended data in order to identify latent themes which differentiate situations for behaviour problems, and it was felt two contextual groupings were apparent: *Situations which threaten the self-concept*, and *Situations which do not threaten the self-concept*. See operationalised definitions of these contexts below. These definitions were utilised to categorise children into two groups: the self-concept group (SC group) and the non-self-concept group (non-SC group).

4.3.1 Contextual Classification Definitions

Situations that may threaten self-concept
Events that may diminish the child's perception of self-competence or self-esteem (these may be due to another person's actions i.e. criticism, bullying, or the outcome of the child's performance). *Situations which may magnify the child's perceived difficulties, limitations or disability, when in comparison to other children (in other words when there is clear frame of reference available i.e. when in competition with others, when marks are allocated) or not (i.e. when they have not achieved their own set goals/expectations).* *Situations that may jeopardise self-concept may be due to external forces -where the child has no active role in the occurrence or outcome of an event but it has the capacity to support a negative self-perception, or internal forces – where the child has perceived the event to be highly aversive and as a threat to their self-image. The child might clearly attribute the occurrence of the situation to their own specific or general failings, or not.* *N.B. A specific incident may not be mentioned, but instead, a wider context that the child tries to avoid/finds aversive due to its capacity to endanger the child's self-perception.*

Situations that do not threaten self-concept
Events that are not expected to impact the child's self-concept, as the situation may be deemed separable and does not occur as a reflection of the child's ability, performance or behaviour. *Situations that produce a non-preferred outcome for the child- usually due to external forces that the child has no control over (i.e. the child cannot have/do something they want, plans/events are changed).* *The incident may be determined by the performance of a favoured particular entity (i.e. a team supported by the child) but the result is not directly determined by the child's ability.* *The child usually attributes the blame of the instance to another person (i.e. when the outcome is subject to the permission of a person in authority) or incident (i.e. when a perceived unfair act occurs, which may be intentionally dictated by another person or not).*

Inter-rater reliability was ascertained after transcription of audio-recorded interviews with parents. The procedure consisted of two independent raters determining if the parental interview responses describing an emotionally salient situation which they deem to be the most negatively impacting for their child, is indicative of one contextual definition or the other. An interrater reliability analysis using the Kappa statistic was performed to determine consistency in categorisation among raters, which demonstrated a near perfect agreement (κ= 0.86, p <.0.001). This resulted in 40 children classified as members of the SC group and 23 as members of the non-SC group. Unsurprisingly, many of the children who were more affected by the criticism and failure contexts became members of the SC group and those more affected by the disappointment and unfairness contexts became members of the non-SC group. However, this was not always the case (an example of this will be presented below).

Examples of parent's contextual descriptions interpreted by researchers as illustrations of SC group classification are as follows:

Table 10. SC group descriptions

***1.**"So I suppose when he cannot do homework and maths, because it's a problem we have with him- the maths, then he gets very agitated. That would be very important for him, when he cannot do maths, he gets very agitated"*
***2.** "'if he doesn't win the game he will take the ball up and throw it. He will give up, walk away, he'll swear…he could possibly come second if his wee sister comes behind him. I've seen situations like that where he can maybe manage that where he feels like he's not actually losing, someone else is coming behind him."*
***3.** "He puts himself down all the time. Say he does really good work he'll come into the house and he goes "my teacher said that's really good work but it's not" and he'll crumple it up "it's crap" and he'll throw it in the bin. Like he thinks everything he does isn't good. He thinks people tell him lies. If you say "you done such a good job!" He'd say "Why you lying?"…He says "I'm stupid" and he's not stupid, he's not stupid."*
***4.** "Child was completing a cutting exercise in school and after the task finished, his teacher said that he needs to work on his cutting, so they will do it again the following day. The child became very upset and said "I didn't do it right, you're disappointed in me."…he feels that he fails at everything, even simple tasks like closing the fridge properly or not walking as fast as someone else. He is extremely hard on himself….but if someone said to him, "no (child's name), you're a good boy", he'll say "No I'm a bad boy."*
***5.** "…she went to mass to practice for her first communion... she was fine, she went over into mass fine and apparently a few kids had been laughing at her and she just*

kicked and she screamed, she tried to run out of mass and I had to be phoned to bring her home and the only alternative the teacher said was to suspend her…"
6. *"Last Saturday was his holy communion and he had been asked to do a prayer and when the teacher asked him to do the prayer, he thought she made a mistake 'cause he can't read- 'cause in his head he can't read the same as the other boys. So she'd given him a two line one, you know, and he practised, he practised, he practised…So when he went up on the altar, he'd got himself really nervous at the actual communion…and he said the response before he said the prayer...but I knew by the face of him when he came back down from the altar, the head was down, he was annoyed at himself, he thought he failed it."*
7. *"Sports day would be a big thing…he says sports day is the worst day of his life, that was his exact words to me. So we're talking say February, Sports Day's in June, he'll say "Mum I know I'm gonna be sick on sports day this year, I'm just gonna be sick…or I'm gonna lose my trainers". Every single one he comes last in, every race... And then at the very end I'll go over and say "You did brilliant" and all and he'll say like "Why you saying that? I came last, that's not brilliant Mummy! Don't say it's good, I came last."*
8. *"School report. And because he only saw below average, he didn't see what the comments were. So one of the sheets was ripped up. The comments were "he's making progress, he is trying hard". He didn't see that, he just saw "below average" in three things. That's really hard for him…he doesn't like to fail, he doesn't like to think that he is not good enough. He doesn't take too well to being criticised either…"*
9. *"Her and a wee boy in school fight. He's ginger and she is ginger so when he calls her ginger, there's murder even though she's ginger…so really it's when*

people try to put her down…She met the wee boy outside school and went after him for a fight...the wee boy ended up with baldy patches all on his head. ...he called her ginger...when people call her fat, she won't eat for a week ... it's kids being kids"
10. *"The wee boy over there calls him a retard…so he would just totally freak out. He'd come in here raging and crying and looking for something to go out and batter the wee boy with but he would never do that... he's all mouth…He'd say "I hate myself, I want to die, why was I born?"-things like that."*

Contextual information provided by parents which were deemed to be examples of non-SC group classification are as follows:

Table 11. Non-SC group descriptions

1. *"Bedtime is difficult. He wanted to play 'Connect 4' with his sister. She wanted to brush her teeth first. He threw the whole game down the stairs. He just explodes, takes a while to calm him down. He just doesn't accept it…"*
2. *"Last week, the grand national, his horse didn't win so he ran out and wrecked the place. He couldn't take that. That night he didn't really sleep so he was in a bad way all day. He said "This is the worst day of my life"...he screamed "Aww come on! Could this day get any worse, it's not fair! They didn't even mention my horse!"*
3. *"it's getting the phone taken off him or the xbox...if he is taken away from his time, he has an outburst...he would lift the controller and throw it or he would lash out at you."*
4. *"She's very noticeable with things not being shared out correctly. She would fly off the handle, with things like "he's got more than me, she's got more than me." You know if you give her a treat for behaving herself and then you give her brothers one but if she's doesn't get a treat because she didn't behave herself, she would scream the place down, saying "that's not fair, that's not fair."*
5. *"...say she has been promised something, for example we were meant to go away on holiday this year and basically we couldn't afford it.... and she sort of didn't speak to me for days and withdrew into her room and I kept asking what was wrong. Then she cried saying her friends were going on holiday."*
6. *"One day we went to go to (location name) swimming pool but when we got there it was actually closed .... and he couldn't understand and had a big kick off then and*

nothing else was going to do or compromise him then... He cried the whole way back and this went on for two weeks after...he couldn't deal with unexpected change"
7. *"It's all the time, for example if daddy was going somewhere and he thought that he was going with dad, there would be chairs turned over, he would go over to the door, slam the door. He'd be violent."*
8. *"When Man United lose a game, which he has no control over."*
9. *"You know simple things, if he thinks he's going to, say, swimming tonight, and then he's told that he's not going, he would be very disappointed and it takes a long time for him to get back on track."*

The following quote details what was initially identified as an example of a disappointment situation by a parent. And although generally disappointment contexts tend to illustrate non-SC group categorisation (as defined above), the researchers determined that because the child attributed the occurrence of the event to his ASD presentation, and as such, he believed having an ASD diagnosis acted as a barrier to "being picked", it was ascertained that it was appropriate to categorise this context as one which threatens the self-concept.

"Last year there was a school trip being organised for first years for skiing. He became really interested in it. The case was you had to put your name forward for interest and then the school got back to you. But from what I gather there was too much interest and there was a 'names out of a hat' scenario. But because first year was quite tricky (because of his behaviour in school), [Child's name] associated it with him not being picked. Even though he worked out the ratio of how many pupils there were and how many got picked, but because there was already difficulties flagged up with him, that is the reason why they...There is a massive, massive sense

of injustice with [Child's name] in his life. He will always come up with scenarios where there has been an injustice. He will come up with scenarios that have nothing to do with it (his ASD presentation)."

4.3.2 Ranking of Contexts

As part of completing the context measure, parents were asked to rank the four contexts in terms of how negatively impacting they are for their child. And although as illustrated previously, there was not an exact one-to-one mapping of the initial contexts on the resulting contextual classification, in all but one child (described previously) SC group membership was represented by children initially described as having an impairment in criticism or failure contexts. Likewise, non-SC membership was represented by children identified as having an impairment in disappointment or unfairness contexts. Results show that for the children in the SC group, 65% ranked the non-SC contexts (i.e. disappointment and unfairness) as their least negatively impacting contexts, and 57% of the non-SC group ranked SC contexts (i.e. criticism and failure) as their least negatively impacting context. These rankings further support the classification of children into the 2 groups.

4.3.3 Behavioural Profile

Relevant assumptions were checked and t test analyses were conducted to examine group differences across a number of domains. Mann Whitney U tests were carried out if the data was not normally distributed. Firstly, analyses were conducted to assess the internalising and externalising behaviour profiles found in the groups (table 12). T test results suggest there was a significant difference in the expression of internalising behaviour between the groups (t (61)= 2.09, p= .041), with the SC group exhibiting more internalising behaviours than the non-SC group. And indeed, Mann-Whitney U test results indicate a significant difference in externalising behaviour between the two groups (U= 618, p= .020), with more externalising behaviours evidenced in the non-SC group. However, it is important to note that the majority of children in both groups presented with internalising *and* externalising behaviour, 90% in the SC group and 78.3% in the non-SC group. Whereas, 2.5% in the SC group and 17.4% in the non-SC group presented with externalising behaviour only and 7.5% in the SC group and 4.3% in the non-SC group presented with internalising behaviour only. There was no significant difference in these behaviour profiles between the two groups (x^2= 4.446; df= 2; p= .108).

Table 12. Group Differences in behaviour profile and emotional salience for the SC group (n= 40) and the non-SC group (n= 23)

	SC group	**Non-SC group**	**Statistic**
	Mean (SD)	Mean (SD)	
Internalising	3.70 (1.99)	2.61 (2.02)	t=2.09, df=61, p=.041, d= 0.54
Externalising	3.20 (1.54)	4.04 (1.15)	U=618, p=.020, r= 0.29
SAM_Valence	1.88 (1.02)	1.70 (0.88)	t=0.71, df=61, p=.482, d= 0.18
SAM_Arousal	3.23 (2.19)	2.13 (1.58)	U=312.5, p=.028, r= -0.27
SAM_Dominance	2.98 (2.04)	4.39 (3.43)	t=-2.06, df=61, p=.044, d= -0.53

SC group= Self-concept group, Non-SC group= Non-Self-concept group, t= t-test, d= Cohen's d, r= Cohen's effect size

4.3.4 Clinical Impact of Behaviour

The clinical impact scores showed a large majority of the children in both groups scored within the abnormal range (SC group= 90%; Non-SC group= 95.7%), with the rest of the children scoring in the borderline range (SC group= 10%; Non-SC group= 4.3%). Notably there were no children who presented in the normal range of functioning following exposure to the emotionally salient context in question.

Analyses indicated no significant difference in impact scores between our two context groups (t= .003; df= 61; p= .998).

4.3.5 Emotion salience ratings

The emotional salience of the context identified as the most negatively impacting was measured through the use of the SAM (Bradley & Lang, 1994). As detailed in table 12, findings show no significant difference for the valence scale between the two groups, yet, significant differences pertaining to the arousal (U= 312.5, p= .028) and dominance subscales (t (61)= -2.06, p= .044) were found. The SC group reported higher arousal levels in relation to their context and the non-SC group reported higher levels of dominance in their context.

4.3.6 Diagnostic Presentation

Children were grouped in relation to whether they had a diagnosis (n=42) or not (n=21), with 66.6% of the total sample presenting with a diagnosis. Importantly, results indicate there were comparable numbers of children in each group with and without diagnoses: 67.5% of children in the SC group had a diagnosis, and 65.2% in the non-SC group also had a diagnosis. Additionally, the sample were further grouped in accordance with diagnostic status into: children with ASD, children with no diagnosis, and children with a genetic syndrome (e.g. Downs Syndrome, FASD and Neurofibromatosis type II) (n= 54). Results show similar proportions of diagnostic spread across the two groups. In the SC group, 47.5% presented with ASD, 38.2% had no diagnosis and 14.7% presented with a genetic syndrome, whereas in the non-SC group, 40% presented with ASD, 40% had no diagnosis and

20% had a genetic syndrome. There was no significant difference in diagnostic presentation between the contextual groups (x^2= .363; df= 2; p= .834).

4.4 Discussion

Insight into emotionally salient situations which resulted in maladaptive emotional and behavioural responses in children was achieved through parent report. The development of a new measure aimed to examine such situations in greater detail, together with the profile of behaviour displayed in response to the situation, and the clinical impact of the behaviour presented. Situations or contexts of interest were informed through the emotion paradigm literature, and published and unpublished parental interview data concerning antecedent events to maladaptive behavioural responses, and were then subsequently included in the context measure. The four contexts included disappointment, perceived unfairness, perceived failure and criticism. In-depth descriptions of such events were examined by researchers and a meaningful discrimination was made, which resulted in children being assigned into 2 groups: the Self-concept (SC) group and the non-Self-concept (non-SC) group. Children in the SC group were more negatively affected by situations which threaten their self-concept, or supports a negative self-perception, whereas the non-SC group were more negatively affected by situations which do not threaten the self-concept, or their occurrence is not perceived to reflect their ability or self-worth.

The classification of children into these two groups is supported by findings which suggest that the majority of children in both groups are least affected by situations which are indicative of membership in the other group. In other words, when the four contexts of interest were ranked in relation to their negative impact on the child, the majority of parents of the SC group ranked situations which are generally perceived as examples of contexts which do not threaten the self-concept (e.g. disappointment and unfairness) as the least negatively impacting, and vice versa. Additionally, examination of the descriptions extracted from parents resulted in very high inter-rater reliability of the classification of the two groups.

Data pertaining to clinical impact, as determined by the impact supplement of the SDQ indicated that a large majority of children in both groups presented with functioning indicative of the abnormal range. These results suggest that the contexts in question are emotionally salient to the children and thus, elicit clinically relevant behaviour responses. The emotional salience of the contexts was further demonstrated by the comparable valence scores, obtained by the SAM (Bradley & Lang, 1994) between the two groups. While results indicate a significant difference in scores pertaining to the arousal and dominance subscales between the groups, feedback from parents during testing suggested that these subscales may not be as appropriate as the valence scale for assessing emotional salience between groups. For example, many parents stated that they *"can't tell"* where their child would fall on the arousal scale. Indeed, as one parent illustrated, *"she looks very blank/emotionless when angry"*, which resulted in the parent selecting the low arousal item, when in fact the context may have been very arousing for the child in question. Additionally, many associated the dominant/in control end of the dominance scale as representing externalising behaviour, and the submissive/not in control end as representing internalising behaviour. Others felt unsure about judging how in control their child feels, as their outward behaviour may look *"very dominant and strong"* but inwardly they may be feeling *"very small"*. Previous research has reported that the dominance subscale may elicit more inconsistent responses, as studies have found negative correlations (Bradley & Lang, 1994) or only weak positive correlations (Moors et al., 2013) between the dominance scale and the other subscales. And due to parents' lack of confidence in rating their child's arousal levels correctly, it was deemed the valence subscale may be the most valid measure of emotional salience for our sample.

The behavioural profile presented following emotionally salient contexts was ascertained through the development of the context measure. Results indicated significant differences in behaviour profile displayed between groups (with more types of internalising behaviour expressed in the SC group and more types of externalising behaviour expressed in the non-SC group). Yet, a large majority of children in the SC group and the non-SC group displayed a mixed behaviour profile, that is both internalising and externalising behaviour. This mixed behaviour profile challenges the perception that individuals are either 'internalisers' or 'externalisers' and thus, suggests the distinct contextual impairments, as identified in this work, are not simply a reflection of internalising or externalising symptomology. Indeed, these findings suggest that although a context that negatively impacts the internal view of the self may be more emotionally salient for a child, the emotional/behavioural responses which follow may take many forms. Therefore, the assignment of these contextually-specified groups is not merely separating children with internalising behaviour, from those with externalising behaviour. Indeed, research shows that internalising and externalising behaviour significantly covary (Lilienfeld, 2003). It is recognised that some of the behavioural responses utilised in the context measure (and as illustrated in Table 9) could be conceptualised as affective responses or thoughts. However, because this measure heavily relied on the CBCL for the description of such responses and also utilised the classification of internalising and externalising behaviour profiles, which has long been adopted in developmental clinical research, it was ascertained to be appropriate to conceptualise the responses in such a way.

Further, findings show a comparable diagnostic spread presented in both context groups. This is important as it suggests that categorisation into one of these context groups is not dictated by diagnostic presentation. And given that EF and ER have been identified as transdiagnostic factors, the even diagnostic spread across the groups allows us to further examine this argument.

4.4.1 Contextual discrimination

While there is a dearth of literature examining the importance of contextual variability in child behaviour difficulties, and to our knowledge, none which have investigated the specific contextual distinction made in this work, there is growing support for approaches which aim to uncover clinically meaningful variation in behavioural dysfunction across situations (Dirks et al., 2012). Previous research assessing contextual variability have mainly focused on informant discrepancies in behavioural presentation (De Los Reyes, Henry, Tolan, & Wakschlag, 2009; De Reyes & Kazdin, 2005; Dumenci, Achenbach, & Windle, 2011).

Other work has examined reciprocal patterning of behaviour across different social school-based situations, as well as the likelihood of specific behaviour profiles (i.e. internalisers, externalisers and mixed) to encounter such aversive social situations

(Wright, Zakriski, & Drinkwater, 1999). Interestingly, the aversive contexts assessed by Wright et al. (1999) were representative of SC contexts, as defined in the present study. Examples of these contexts include "*Adult gave the child a warning* (or punished them)*"*, "*Peer teased, provoked, or ridiculed"*, *"Peer bossed, bullied, or threatened"*. And while generally, the children displayed differing behavioural responses (e.g. aggression, withdrawal), indicative of different behaviour profiles, the contexts did not discriminate in the occurrence of dysfunctional responses between the behaviourally-defined clinical groups. As the situations were representative of SC contexts and all children, irrespective of their behaviour profile, showed maladaptive responses to them, the results support our finding that SC impairment is evidenced in children across traditionally defined behavioural groups. However, it is important to note that direct comparisons cannot be made between this study and the current study as corresponding aversive situations, indicative of non-SC contexts were not assessed in this work.

Dirks et al. (2012) argue there is increased evidence that suggests children's behaviour difficulties vary meaningfully across contexts. They propose contextual impairment, as demonstrated in the present study, may constitute distinct phenotypes, and thus, unearthing the underlying mechanisms which contribute to these distinct phenotypes may yield significant gains in furthering the field of child psychopathology. Indeed, in order to investigate such discrete phenotypes, it is imperative to develop new ways of assessing contextually-specified behaviour by furthering conceptual, methodological and statistical approaches (Dumenci et al., 2011). And the examination of functional characterisations, as adopted by the present study, has been identified as a promising possibility to elucidating the complex dynamics between clinically-relevant behaviour and specific contextual impairment (Dirks et al., 2012).

4.4.2 Self-concept

The distinction which resulted between the groups in the present study pertained to the impact of the context on the self-concept. Self-concept represents "…the person's view of her/himself, as well as the extent to which the various components of this self-view (i.e., academic competence, competence with peers, physical attractiveness) fit together into a coherent structure" (Harter, 1999). The component process model (CPM), posited by (Scherer, 2009) conceptualises how emotion is subjectively appraised following events. This model proposes that events are evaluated through a series of appraisal checks, following a fixed order, which subsequently inform on behavioural responses to such events. These appraisal processes or checks evaluate the significance of the event, firstly, in relation to its relevance (which encompasses novelty, familiarity and predictability), as well as it's intrinsic pleasantness and importantly, the relevance of the event to the individual's goals or needs. The next appraisal check to be encountered corresponds to the implications of the occurrence of the event, e.g. how likely is it that the consequences will take place? How conducive or obstructive is the event to achieving my goals? Is the situation different from what was expected? The next evaluative process considers coping ability in response to the event, e.g. Who is responsible for the occurrence of the event and what was their intention? Do I have any control over the consequences? Can I adjust to these consequences? And finally, the last appraisal check relates to the normative significance of the event. In other words, the overall evaluation of how compatible the occurrence of the event is to the self-concept, values, social norms and moral status. This last appraisal check requires the most high-level processing, as it relies on the consolidation of extensive knowledge of the event, which then needs to be utilised by way of comparison with other contextual representations. Therefore, as the distinction between our groups pertains to the potential of the context to threaten the child's self-concept, it could be argued that it is at this final appraisal stage where our two groups discriminate. Perhaps, it is at this stage that the SC group members are more comparably negatively affected. In other words, perhaps the SC group members appraise the event as being incompatible to their internal and external standards, with respect to their self-concept. More consideration of this model is presented in Chapter 5.

4.4.3 Future work

Undoubtedly, there is substantial lack of pertinent previous research to allow direct comparisons to be made with the results of the present study. Therefore, there remains a distinct gap in the literature for efforts to contribute to the understanding of contextual manifestations of child psychopathology. And in particular, future efforts to discern underlying deficits which contribute to SC and non-SC contexts as identified in this work, is warranted. Of course, the current work focuses on the role of EF and ER in contextual dysfunction (as presented in the following chapter). However, there may be other promising possibilities to investigate which contribute to the expression of contextual impairments as identified in this work. Examples include: adverse childhood experiences (ACEs), attribution styles, parenting stress, personality traits, such as narcissism, to name a few. Further, the present findings strongly suggest more transdiagnostic endeavours are paramount in identifying both person and environmental influences on contextually specified behaviour profiles.

4.4.4 Limitations

A possible limitation of the present study pertains to the validity of the context measure developed by the researchers. It is important to note that while well-validated measures were included in the measure, omissions and adaptations were made to such measures, to allow for reduced participant demands and the provision of essential contextual information. Yet, this tool was piloted with members of academic staff as well as clinicians, in order to increase its validity. A further limitation may be the use of the SAM as a parent-report, as our results suggest the difficulty shown by parents in ascertaining representative responses to the levels of dominance and arousal felt by their child. Therefore, demonstrating these scales may not yield valid results when utilising the measure via parent-report.

It is possible another limitation may relate to the prior selection of specific contexts of interest. And while this was to stimulate discussion about important contextual impairments, this prior selection may have directed the responses towards describing situations only indicative these contexts. Thus, potentially limiting the variation of relevant situations considered. However, it is important to note that the context measure included an "other" option in the identification of contexts which parents deem to be the most negatively impacting for their child. This admission of allowing parents to describe a situation which may not fit into the previously selected contextual definitions, mitigates the potentially confounding nature of presenting already identified contexts. Interestingly, no parents used the "other" option when describing contexts which they deem to be the most negatively impacting on their child, thus, providing evidence that the contexts of interest were indeed emotionally salient and clinically relevant. Furthermore, an important limitation of the study pertains to the forced nature of the task, that is, parents were requested to select one context as the most negatively impacting, when 2 or more may have been equally negatively impacting. This forced choice questions the ecological validity of the study, particularly when the decision informs the differentiation of children into functional groups which consequently provides the basis for further analyses.

4.4.5 Conclusion

The current findings are consistent with the idea that emotionally salient contextual information is important to consider when examining behaviour problems. Due to the suggested clinical relevance of the distinction between our contextually-specified groups, and previous research findings illustrated in this chapter, there remains an intriguing possibility that children who are more negatively affected by self-threatening information may present with a specific control process profile, which incorporates both EF and ER processing. Therefore, further examination of EF performance and ER strategy usage in SC and non-SC contexts is warranted. Furthermore, the current findings suggest that adopting a transdiagnostic approach when investigating maladaptive behaviour in response to emotionally salient contexts is highly recommended. Therefore, additional insights into how control processes are adopted as a result of such contexts in transdiagnostic samples may be achieved through further investigation.

Chapter 5

Exploring the role of Executive Function (EF) and Emotion Regulation (ER) in emotionally salient contexts

5.1 Introduction

Historically, understanding the self has been a prominent feature of philosophy and psychology and more recently, neuroscience. There are many concepts of self in the literature, which cross multiple sensory and cognitive domains (Northoff et al., 2006). For example, the spatial self (Noel, Cascio, Wallace, & Park, 2017; Schwartz & Halegoua, 2015), the verbal self (Yeung & Wong, 2004), the emotional self (Devinsky, 2000), the autobiographical self (Blinder, 2007; Wang, Lee, & Hou, 2017) and the social self (Brewer, 1991; Dickerson, Gruenewald, & Kemeny, 2004) to name a few. These domains differ in relation to the modality of the stimuli or content involved in the processing of the self. Yet this 'non-task/modality-specific self-processing', which encompasses many concepts of self across diverse domains, is commonly referred to as 'self-referential processing' (Northoff et al., 2006). Self-referential processing is utilised when information from the environment is perceived as bearing significance to one's own person (Meffert, Blanken, Blair, White, & Blair, 2013). The 'self' involved in self-referential processing is not viewed as a fixed entity, instead it is assumed to be context-dependent, being shaped and manipulated by subjective experience (Northoff et al., 2006) and is a key component of the emotional self-concept (Lumma, Valk, Böckler, Vrtička, & Singer, 2018). In line with this, in their meta-analysis assessing the neural underpinnings of self-referential processing, Northoff et al. (2006) describe self-referential processing as the ‘experiential self’ which encompasses how an individual reflects on how they themselves are related to the stimuli they encounter in the world.

Self-referential processing has been a feature of recent neuroscientific investigation (Chen et al., 2008; Frewen et al., 2011; Herold, Spengler, Sajonz, Usnich, & Bermpohl, 2016; Knyazev, 2013; Salomon, Levy, & Malach, 2014; Yang, Qi, & Guan, 2014; Yoshimura et al., 2014; Zhao et al., 2018). The neural basis of self-referential processing is believed to reside mainly in the cortical midline structures (CMS) (Northoff et al., 2006), with further fMRI evidence suggesting a role for the medial prefrontal cortex (mPFC), and specifically the ventral portion (vmPFC) particularly during self-referential processing that relates to the importance attached to one’s self-view (which the authors termed ‘emotive investment’) (D’Argembeau et al., 2012; Kim & Johnson, 2015; Wagner, Haxby, & Heatherton, 2012). The processing of emotion is an integral feature of self-referential processing (Lumma et al., 2018). The vmPFC, along with other regions that have been linked to SRP (e.g. the anterior and posterior cingulate cortex, the lateral, inferior and medial temporal cortices, and the posterior parietal lobe) have been identified as areas of the “default mode network” (DMN) (Gusnard, Akbudak, Shulman, & Raichle, 2001; Messina, Bianco, Cusinato, Calvo, & Sambin, 2016; Raichle & Snyder, 2007; Salomon et al., 2014). This network facilitates on-going intrinsic activity at rest and shows consistent decreases in activity during goal-directed task engagement (Raichle & Snyder, 2007).

Importantly, clinical research suggests that the inability to inhibit such self-reflection at times, can negatively affect cognitive control performance particularly in individuals with depression (Wagner et al., 2013). Indeed, in a later study, Wagner, Schachtzabel, Peikert, & Bär (2015) reported a competitive interplay between emotional processing brought on by self-referential processing , in individuals with depression, and EF processing, thereby resulting in poorer EF performance. Recently, dysfunctional interactions between networks that facilitate self-referential processing (DMN) and cognitive control (frontoparietal network, FPN) have also been found in healthy adolescents (Alarcón, Pfeifer, Fair, Nagel, & Sullivan, 2018). The researchers were interested in examining this dysfunctional relationship in adolescence in particular, as it is a period of high mood volatility, with increased rates of depression. Interestingly, Alarcón et al. (2018) found that co-rumination (i.e. rumination with a same-gender peer) explained the deficits in EF performance following self-referential processing, suggesting a link between self-referential processing, EF and this maladaptive ER strategy during adolescence. Indeed, in a review of fMRI studies, Nejad, Fossati, & Lemogne (2013) also found abnormal interactions between networks associated with self-referential processing, and networks known to support rumination, in patients with major depressive disorder (MDD).

5.1.1 Self-focused ER

Previous research has identified rumination as a specific self-focused ER strategy, which is highly symptomatic of mood disorders (Aldao, Sheppes, & Gross, 2015). The persistent and repetitive brooding over aversive events or perceptions- indicative of rumination encourages the development and maintenance of anxious and/or depressive states. Another maladaptive self-focused strategy, which is thought to also contribute to psychopathology, is self-blame (Bornas, Tortella-Feliu, Balle, & Llabrés, 2012; Garnefski et al., 2001). Both rumination and self-blame are categorised as self-focused cognitive ER strategies because they engage heightened internal evaluation, whereas other strategies are concerned with external factors, such as an event/situation, or others (Bornas et al., 2012). Therefore, in the current research, because of the contextual classification between contexts that threaten the self-concept and those that do not (as highlighted in the results of Chapter 4 — section 4.3.1), examining self-focused maladaptive ER strategies in particular, was a central aim.

Other lines of the 'self' inquiry prevalent in the literature include examinations of the effect of self-salience and self-esteem on mental health. Many of these examinations have resulted in relationships between such concepts and the emergence of internalising and externalising symptoms (Rosenfield, Lennon, & White, 2005) and executive process deficits (Capelatto, Lima, Ciasca, & Salgado-Azoni, 2014; Gyurak et al., 2012). However, further discussion of these concepts of the self are beyond the scope of this thesis, thus self-focused ER and contexts that may threaten self-perception remain the primary focus.

5.1.2 The role of EF in self-focused ER

Due to the suggested clinical relevance of the distinction between our contextually-specified groups, and previous research findings, there remains an intriguing possibility that children who are more negatively affected by self-threatening information may present with a specific control process profile, which incorporates both EF and ER processing. The Component Process Model (CPM) by Scherer (2009) was discussed in section 4.4.2 as a possible explanation for our contextual group classification. Therefore, if we consider the appraisal stages outlined in the model, how might EF play a role in these processes? Scherer (2009) describes the evaluative stages of the CPM as recursive processes, that while assuming a fixed order, are continually repeated and updated in response to changing contexts and as a result, form more refined evaluations. Updating and perhaps switching executive processes therefore appear to be particularly aligned with recursive evaluative processing, as described by this model. Therefore, an examination of group differences in updating and switching performance in particular, may facilitate the understanding of the role of executive processes in appraising emotionally salient contexts. In the present work, further examination of EF performance and ER strategy usage in SC and non-SC contexts was therefore important.

5.1.3 Switching and self-focused ER

While the literature presents contrasting findings regarding the role of specific EF processes in ER (Joormann & Tanovic, 2015), there is evidence to suggest that switching plays a role in self-focused maladaptive ER strategies, such as rumination (De Lissnyder, Koster, Derakshan, & De Raedt, 2010; Whitmer & Banich, 2007). Davis & Nolen-Hoeksema (2000) reported an increased tendency to attend to one’s depressive symptoms indicates perseveration and in turn, reduced cognitive flexibility. Furthermore, individuals with increased usage of self-focused maladaptive ER have been reported to show more deficits in switching from self-generated thoughts to external environmental content (Rochat, Billieux, & Van der

Linden, 2012). This led the researchers to suggest that switching impairments may underpin maladaptive self-referential thinking, associated with negative affect. Similarly, Beckwé, Deroost, Koster, De Lissnyder and De Raedt (2013) found switching deficits in individuals who were high-ruminators and high worriers in comparison to those who presented as low ruminators and low worriers. Importantly however, these findings were only significant when participants were asked to switch using personally-relevant content. These findings therefore point towards an interaction between switching and emotion regulation — more specifically, self-focused emotion regulation.

5.1.4 Updating and self-focused ER

Sperduti et al. (2017) reported a direct link between updating and implicit ER when individuals are exposed to high-intensity stimuli. Yet, no such effect was found for other executive abilities. Further, in their novel study, Schmeichel & Demaree, (2010) suggested that greater working memory capacity predicted more self-enhancement (and reduced negative affect) following negative feedback regarding the participants' own emotional intelligence. The negative feedback condition as presented in this work aimed to elicit an emotional response following a threat to the self-concept, and as such, increased self-enhancement in this context represents adaptive ER (Koole, 2009). Considering that WM capacity and updating skills are highly correlated (discussed previously), these results further support an important role of updating in self-focused ER. Indeed, evidence suggests increased updating ability facilitates adaptive ER (Hendricks & Buchanan, 2016), while updating impairments underlie maladaptive self-focused ER (Pe, Raes, & Kuppens, 2013).

The link between updating and self-focused ER can be conceptualised if one considers that increased self-focused maladaptive ER encourages prolonged focus on negative self-referential thoughts usually following an emotionally salient event which is perceived as self-threatening. In this sort of situation, to effectively down-regulate this emotional experience, newer information needs to be welcomed into working memory and as such, updating of old information (in this case, negative thoughts about oneself) is required. Therefore, updating may interact in an important way with the relationship between self-processing and emotion regulation.

5.1.5 The present investigation

Analyses were conducted to investigate if membership of our contextually specified groups (SC group and Non-SC group, as described in Chapter 4) could be predicted by EF performance and maladaptive ER, which would suggest distinct control process profiles exhibited by members of the groups. EF was assessed by performance in an online EF battery, and the use of maladaptive ER strategies was determined by parents' responses on the Cognitive Emotion Regulation Questionnaire (CERQ). Additional analyses were then carried out to provide further understanding of the profiles identified. With regard to EF, it was predicted there would be significant differences across different levels of EF between the context groupings. And it was expected there would be significant group differences in the adoption of specific maladaptive ER strategies. Overall, it was hypothesised that EF (at all levels) and maladaptive ER would significantly predict membership of our contextually specified groups (SC group and Non-SC group). In contrast, in line with the discussion in the previous chapter highlighting that deficits in EF and ER appear to cross diagnostic boundaries, it was hypothesised that EF and ER would not significantly predict membership of the diagnostic groups.

5.2 Method

5.2.1 Design

The aim of the current study is to investigate whether executive function (EF) and emotion regulation (ER) predict membership into the contextually defined groups of interest, as presented in the previous chapter. Therefore, the dependent variable was contextual group membership, that is, whether a participant is a member of the self-concept group (SC group) or the non-self-concept group (non-SC group). Executive function was measured through the administration of an online EF battery, developed by our research team building on the results of Chapter 3 and other work. The battery consisted of 11 EF tests: 4 inhibition tests (Stroop, Simon, Flanker, Go-No/Go), 4 switching tests (Colour/shape, Age/Gender, Category/Switch, Global/Local) and 3 updating tests (Letter/Memory, Spatial Updating, Keep Track). Emotion Regulation was measured via parent-report using the Cognitive Emotion Regulation Questionnaire (CERQ) (Garnefski et al., 2001), which is a 9-item likert type scale measure, concerning ER strategy usage.

Logistic regression analyses were conducted to examine the role of EF and ER in predicting membership of our two contextual groups. The EF predictors included in the analysis were *Undifferentiated EF*, *Common EF*, *Inhibition*, *Switching* and

Updating, which were composite scores pertaining to performance on the relevant executive process tests *(see figure 12)*. More information regarding these variables can be found in the Data Analysis section.

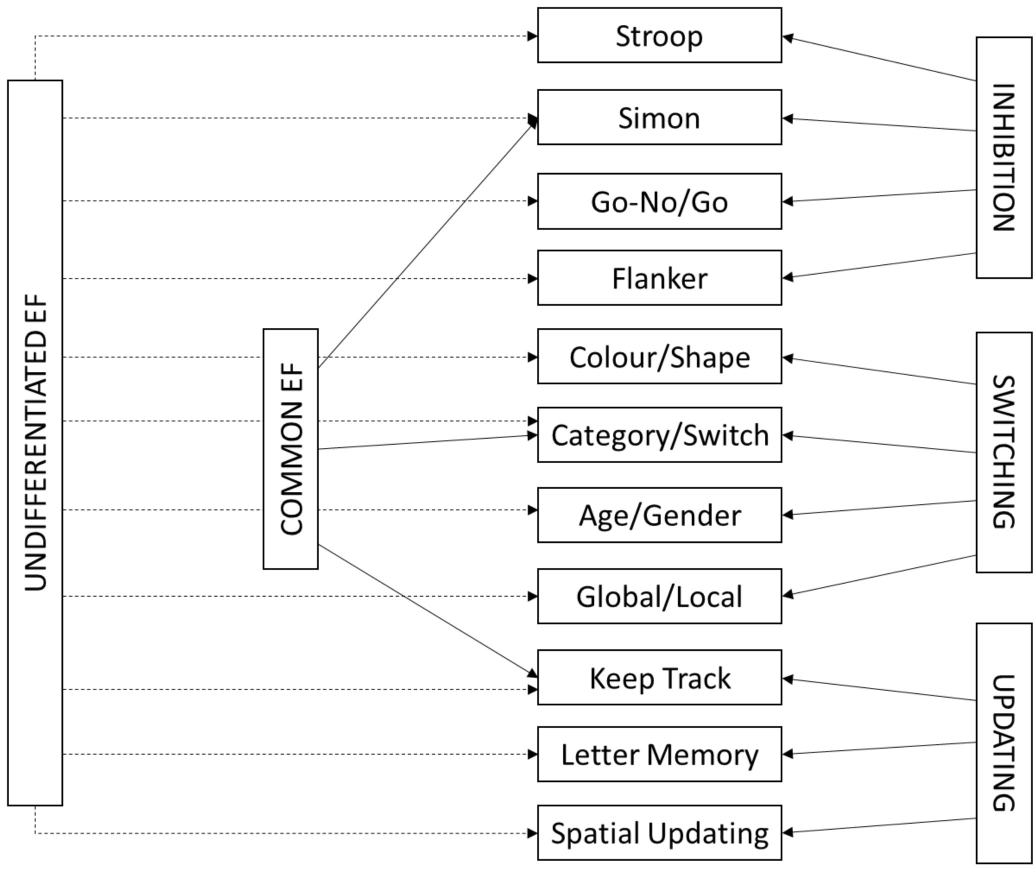

Figure 12. EF battery composites. A depiction of how test performance on the EF battery contributes to the executive process composite scoring.

ER predictors included *Maladaptive ER* (all) – demonstrating maladaptive strategy usage as presented in the CERQ (Garnefski et al., 2001). Maladaptive items concerned the following processes: Rumination, Self-blame, Catastrophising and Blaming Others. Further ER predictors include *Self-focused ER* and *Non-Self-focused ER*. More information on these variables is outlined in the Data Analysis section. It was hypothesised that the control process profiles, composed by EF and ER scores, will more strongly predict membership into our contextually defined groups than diagnostic group membership, thus supporting the view that contextual information is imperative to the expression of control process dysregulation. And that contextual impairment is more important in the exhibition of control process deficits than diagnostic status.

5.2.2. Participants

As outlined in the previous chapter, 63 parents and 63 children, aged between 6 years and 12 years (or up to 16 years if they had an intellectual disability), participated in the study. Again, all participants presented with emotional and/or behavioural difficulties (as determined by their parents and/or teachers), which included children with and without specific neurodevelopmental diagnoses. Participants were recruited through schools, support organisations, Queen's University Belfast and via social media. All but 2 families took part in face-to-face sessions with researchers, while the remainder completed the EF battery online and parents completed questionnaires online and via telephone. However, some data was excluded from EF scores when children failed tests before practice trials (the practice procedure for all tests is outlined in the measures section). These fails were due to inattention or lack of understanding of the test scenario. Furthermore, due to testing fatigue and frustration, which at times resulted in behavioural outbursts following errors in performance during testing, some children did not attempt all tests in the battery. Therefore, 59 complete datasets were achieved for undifferentiated EF, common EF and inhibition. 54 complete datasets were achieved for switching and 47 for updating.

As described in the previous chapter, participants were divided into 2 groups, which was informed by the descriptive data provided by parents pertaining to the context they deem to be the most negatively impacting for their child. The groups consisted of: the Self-concept (SC) group, that is children most impacted by situations that may threaten their self-concept, and the non-Self-concept (non-SC) group, that is children who were most impacted by situations that do not threaten their self-concept.

There were no significant differences in age and estimated IQ between the groups, however there was a significant difference in gender between groups, with 75% of the SC group being male, but only 43.5% of the non-SC group (table 13). There was a comparable spread of children with or without a diagnosis across groups, with 67.5% presenting with a diagnosis in the SC group and 65.2% in the non-SC group. A further breakdown of the diagnoses presented were detailed in previous chapter.

Table 13. Demographic Profile of the SC group (n=40) and the Non-SC group (n=23)

	SC group Mean (SD)	**Non-SC group** Mean (SD)	**Statistic**
Age (years)	9.35 (2.69)	9.93 (3.00)	$t=.772$, $p=.443$
Estimated FSIQ	91.34 (17.36)	97.47 (14.12)	$U=329.5$, $p=.226$
Gender	75% Male	43.5% Male	$x^2=7.389$, $p=.025$

SC group= Self-concept group; Non-SC group= Non-Self-concept group; FSIQ= Full-Scale IQ

5.2.3 Measures

5.2.3.1 Executive Function Online Battery of Tests

EF was measured through the use of an online battery, which consisted of 11 EF tests, 4 inhibition tests, 4 switching tests and 3 updating tests. To instil interest and motivation in engagement with the tests, the battery was gamified, using a child-friendly central character and narrative. The battery begins with the introduction of Bizz, an alien from a faraway planet. He explains that while he is visiting earth, he would like to go on adventures that requires the participant's help. Successful completion of some of the tests by the participants result in the fixing of his spaceship and ultimately, the safe return of Bizz to his home planet.

The administration time of the battery typically ranged between 45 and 60 minutes. Participants were asked to engage with the tests in 3 sections, taking a short break (duration as required) between sections. There was variation in the duration of the breaks across participants, and also the number of sessions to complete the battery. Most children completed the battery in 1 session, however, 6 completed the battery over 2 days. During each test, visual and/or auditory stimuli were displayed on a laptop and participants were required to produce motor responses. For example, during the go-no/go test, participants responded by pressing a button when they were exposed to a specific stimulus, in this case a green cog wheel in the shape of a C, but then withheld that response when another stimulus, a red cog wheel in the shape of an X (which was presented less frequently) was displayed. Completion of each test resulted in a number of dependent measures, e.g. reaction time, proportion of correct responses etc. Therefore, the DV which was deemed most appropriate to report is specified on a test-by-test basis.

5.2.3.1.1 Inhibition tests

5.2.3.1.1.1 Flanker test

Participants were presented with five fish on a screen and were asked to indicate whether the central fish (highlighted by an arrow) was swimming toward the left (by pressing the ‘A’ key on the laptop), or swimming toward the right (by pressing the ‘L’ key). Congruent trials were signified by all five fish swimming in the same direction, and for incongruent trials, only the target fish was swimming in a different direction.

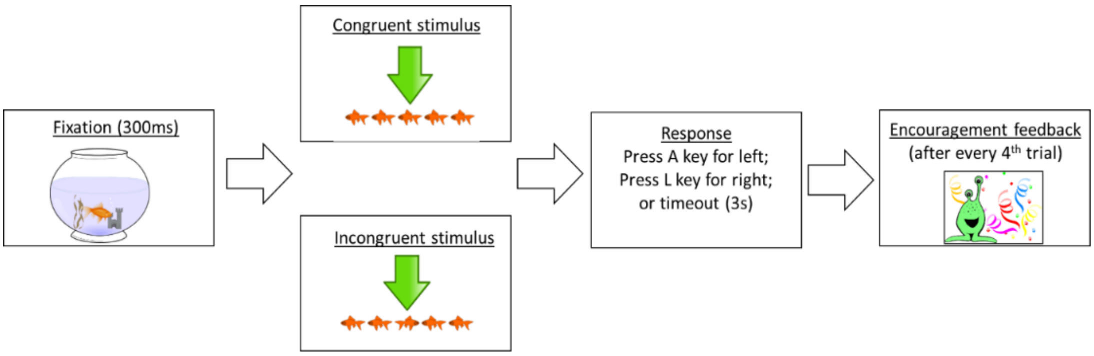

Figure 13. Trial structure of the Flanker test. 48 trials in total.

The test utilised a block-design format, with a block of 4 congruent trials, followed by a block of 4 incongruent trials and so forth. Practice procedure consisted of introduction trials (IT) which presented stimuli and provided a verbal explanation of the test but no response was required, followed by tutorial trials (TT) (4 different trials available) – as per ITs but with responses required and trial feedback provided. Any individual TT was repeated up to 5 times if responses were incorrect or the trial timed-out (no response occurred). The 5th consecutive lack of correct response to a TT led to the child failing the test. Following the TTs, practise trials (PT) (4 different trials) were completed. PTs were as TTs but with reduced verbal description and no trial feedback provided following correct responses. All 4 PTs were presented sequentially but if responses to < 3 PTs were correct then the whole sequence of 4 PTs was completed. Up to 3 repeats of all PTs was allowed. If at least 3 PTs were correctly completed, participants progressed to real trials. Test failure was determined if at least 2 incorrect or timed-out responses occurred in the 3rd repetition of all trials.

5.2.3.1.1.2 Stroop test

In this test, two animals were displayed on screen and participants were asked to select the animal which is bigger in real life. In the congruent trials, the comparative size of the animals in real life were consistent with the pictorial sizes presented on screen, whereas the real size of the animals was inconsistent with the pictorial sizes in the incongruent trials (see figure 14). Participants pressed the 'A' key (on left side of keyboard) for the animal displayed on the left of the screen and pressed the 'L' key (on right side of keyboard) if they selected the animal on the right.

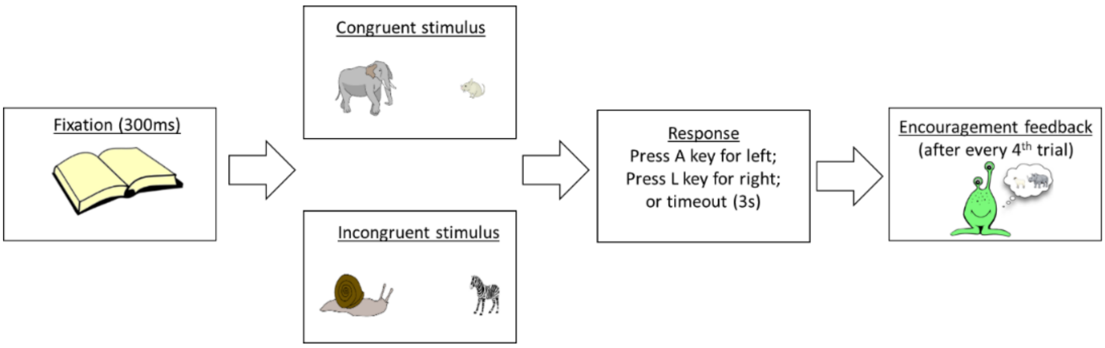

Figure 14. Trial structure of the Stroop test. Block design utilised in 48 trials. Practise procedure as per flanker test.

5.2.3.1.1.3 Go-No/go test

Participants were asked to respond to the “Go” stimulus (C-shaped spaceship part) by very quickly pressing the space bar on the laptop, and to inhibit a response to “No-go” stimulus (X-shaped spaceship part), by not pressing any keys.

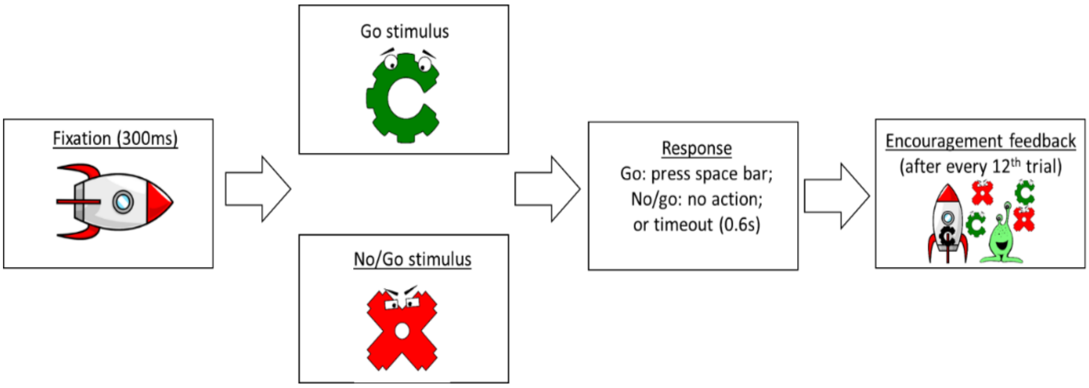

Figure 15. Trial structure of the Go-No/go test. 96 trials in total, with 24 trials displaying the “No-go” stimulus. Practise procedure as per other inhibition tests, except the number of PTs were increased to 9 trials. Participants were required to respond correctly to all PT trials and if this was not achieved on their 3rd attempt, they failed the test.

5.2.3.1.1.4 Simon test

In this test, an arrow was displayed on screen and participants were asked to identify which direction the arrow on screen was pointing toward, while the location of the arrow was manipulated between trials. For congruent trials, the location of the arrow was consistent with the direction the arrow was pointing toward (e.g. the arrow was located on the left side of the screen and was pointing toward the left), whereas for incongruent trials, the location of the arrow on screen was inconsistent with the direction the arrow was pointing toward (e.g. the arrow was located on right side of the screen but was pointing toward the left). Again, participants were required to press the 'A' key for responses indicating the left and the 'L' key for responses indicating the right.

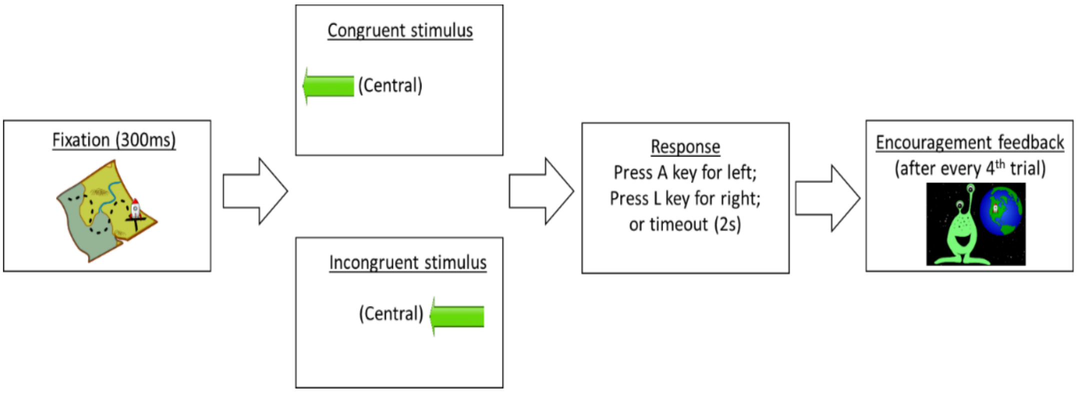

Figure 16. Trial structure of the Simon test. 48 trials. Block design. Practise procedure as per flanker test.

5.2.3.1.2 Switching tests

5.2.3.1.2.1 Category switch test

In this test, participants were required to switch between two tasks. As for all switching tests, there were only four possible target stimuli that were presented. The stimuli were the words "bookshelf, "donkey", "toothbrush" and "pebble". In task 1, participants were asked to decide whether the stimulus was usually found inside or outside of a house. The pictorial cue for this task depicted a house. Participants selected the 'A' key for responses indicating "inside" and the 'L' key for responses indicating “outside” (see figure 17). In task 2, participants were asked to decide whether the stimulus could fit inside a ruck-sack and again, responded by pressing the ‘A’ key to indicate the stimulus does fit inside the rucksack (as depicted by the inside symbol on the bottom left of the screen). Or pressing the ‘L’ key if the stimulus does not fit inside the rucksack (as depicted by the outside symbol on the bottom right side of the screen).

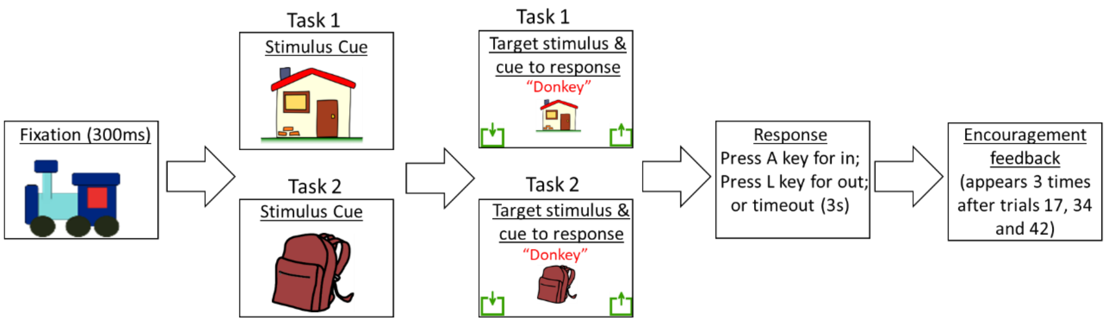

Figure 17. Trial structure of the Category switch test.

There were 51 trials in total. The design consisted of trials alternating in a switch/repeat fashion (that is, alternating between trials requiring participants to switch between tasks, and trials requiring no switching) for the first 34 trials, and following this, a block of task 1 was carried out (between trial 35 and trial 42), which was followed by a block of task 2. The practise procedure consisted of ITs (4 different trials available), in which stimuli and cue to response was presented until the participant’s response or time-out occurred (5s). Each IT was repeated up to 5 times if the response was incorrect or it was timed-out. Verbal and visual feedback was provided. TTs (4 different trials available) were as ITs but with the addition of verbal explanations for the cues for both tasks. Each TT repeated up to 3 times if incorrect or a time-out occurred. If the same IT or TT was not responded to correctly on 5 or 3 occasions respectively, the child was determined to have failed the test. PTs were as per TTs but the time-out was shortened to 3s, there was reduced verbal descriptions of the cue, and no trial feedback was provided for correct responses. All 4 PTs were administered sequentially, but if < 3 PTs in the sequence were correct all 4 PTs were repeated. If at least 3 PTs were correct, and the PT sequence had been repeated 3 times or less, participants progressed to real trials. Test failure was determined if at least 2 incorrect or timed-out responses in the 3rd repetition of all PTs.

5.2.3.1.2.2 Age/gender test

In this switching test, participants were asked to switch between two tasks in which they had to categorise stimuli by age and gender respectively. The target stimuli were cartoons of a young male, a young female, an old male and an old female. If stimuli were presented in the upper part of the screen, participants had to select whether they were young (by pressing the 'A' key) or old (by pressing the 'L' key). Conversely, if stimuli were presented in the lower part of the screen, participants were required to classify them by gender (by pressing the 'A' key for male and the 'L' key for female (see figure 18). Cues for the responses were displayed prior to response.

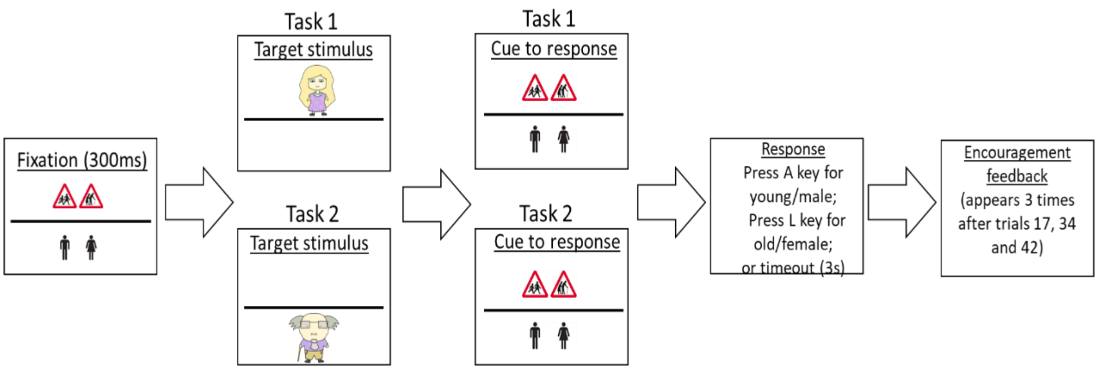

Figure 18. Trial structure of the Age/gender test.

There were 51 trials and a design alternating between switch/repeat trials and blocks of trials (as described previously) was utilised. Practise procedure was as per category switch test.

5.2.3.1.2.3 Shape/colour test

This test required participants to switch between two task sets. In the first task participants were asked to categorise the stimuli (a coloured shape- red and blue circles and squares) by shape (verbally presented cue), whereas the second task required participants to categorise the stimuli by colour (verbally presented cue). The cues for each response were presented in the bottom left and right of the screen (see figure 19). Participants selected the ‘A’ key for responses indicating the shape was a square or the colour was red, and selected the ‘L’ key if the shape was a circle and colour was blue.

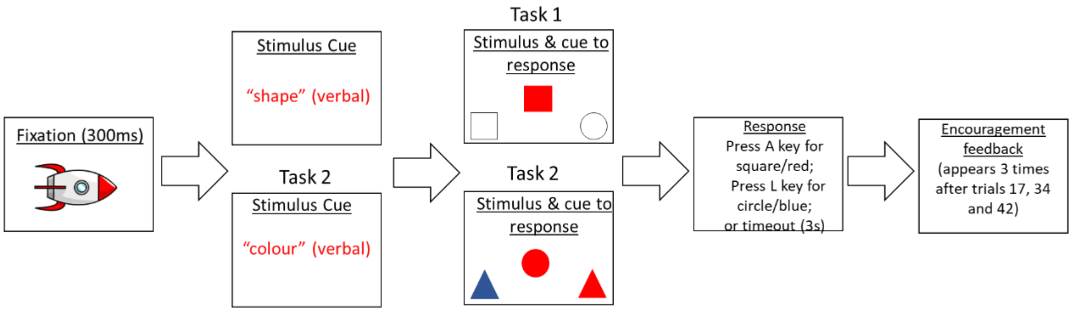

Figure 19. Trial structure of the Shape/colour test.

Again, there were 51 trials in total and a design alternating between switch/repeat trials and blocks of trials was utilised. And the practise procedure was as per other switching tests.

5.2.3.1.2.4 Global/local test

In the global/local test, participants were presented with a shape stimulus which was made of small shapes (a large square or triangle comprised of small circles, or a large circle comprised of small squares or triangles, see figure 20). Task 1 required participants to decide whether the global shape was a square or a triangle and task 2 required them to decide whether the local shapes (the small shapes within the global shape) were squares or triangles. The stimulus cue for task one was a house built of lego bricks, as the participants were asked "What are these toy bricks built to make?" The stimulus cue for task two was a singular lego brick as in this task participants were asked "What shape is each of these toy bricks?" Again, for responses indicating the shape in question was a square (displayed on left side of screen), participants were asked to press the 'A' key and for responses indicating the shape was a triangle, the 'L' key was pressed.

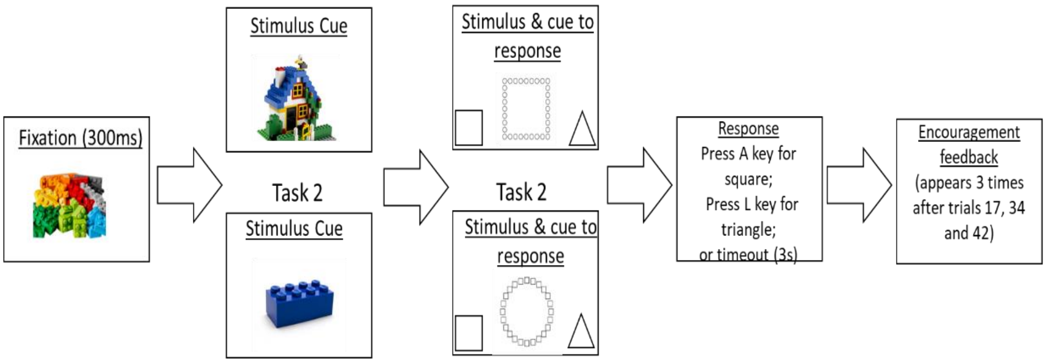

Figure 20. Trial structure of the Global/local test.

As with the other switching tests, there were 51 trials, which consisted of alternate switch/repeat trials and task blocks and the practise procedure was as previously described.

5.2.3.1.3 Updating Tests

5.2.3.1.3.1 Letter Memory test

In this letter memory test, sequences of letter and animal pairings were presented pictorially on screen and verbally e.g. “B for Bear”. Participants were required to select the last 3 animal/letter pairings presented in the sequence. The response picture displayed all 12 animal/letter pairings on screen and participants were required to click on the relevant stimuli.

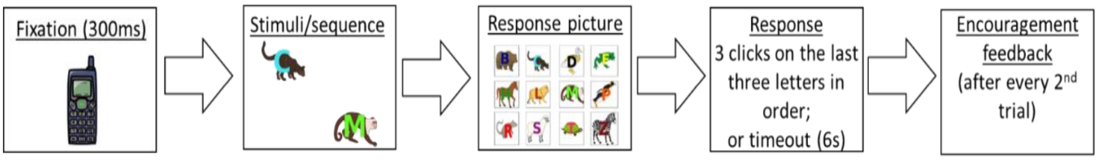

Figure 21. Trial structure of the Letter Memory test.

There were 24 trials in total, and the number of updates per trial (determined by the length of the list of stimuli presented) gradually increased from 1 to 8 as the trials progressed, with an additional update required every 3 trials.

The practise procedure included 12 ITs, which tested children's ability to hold each stimulus in mind and associate it with the corresponding response, presented a verbal explanation of the test and each possible stimulus followed by the response picture (as illustrated) until a response or time-out occurred (5s). Verbal and visual feedback was provided. Each IT was repeated up to 5 times if there was an incorrect response or a time-out. TTs (up to 4 available) were as per ITs, but they also presented an update of the target stimulus with a verbal description of the updating required. TTs were repeated up to 3 times if incorrect or a time-out occurred. A child failed the test following 5 or 3 consecutive incorrect responses to an IT or TT respectively. PTs (up to 4 available) were as TTs but with reduced verbal description of the cue, and no trial feedback for correct responses. All 4 PTs were presented in sequence, if fewer than 3 PTs were correct, then encouragement feedback was presented and the whole sequence was repeated again. If at least 3 PTs were correct, participants progressed to real trials (as illustrated). Test failure was ascertained if at least 3 incorrect or timed-out responses occurred in the 3rd repetition of all 4 PTs. Additionally, updating tests ceased if children provided 3 incorrect test trial responses.

5.2.3.1.3.2 Keep Track Test

In this test, participants were presented with sequences of stimuli, shapes on the left side of the screen, and animals on the right side of the screen. A response picture displaying all 9 shapes and 9 animals was presented and participants were asked to click on the last shape and last animal presented in the sequence.

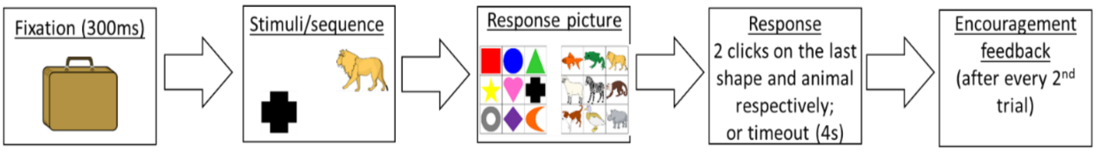

Figure 22. Trial structure of the Keep Track test.

24 trials in total, with additional updates included after every 3rd trial completed. Practise procedure was as per Letter memory test (as above). Thus, since there were 18 individual stimuli, there were 18 ITs (as opposed to 12 in the Letter Memory test).

5.2.3.1.3.3 Spatial Updating Test

The spatial updating test required participants to hold the location of a planet on a grid (see figure 23) in their memory and update its location based on presented arrows, which directed the change in location across the grid. Participants were then asked to click on the square on the grid where the planet should now be located.

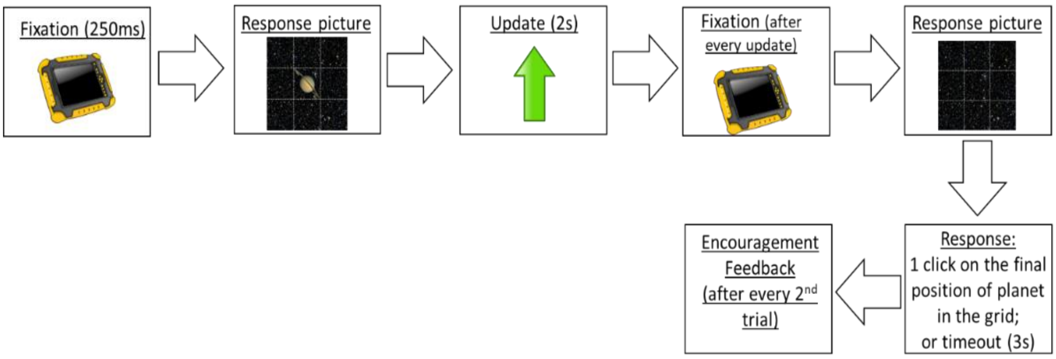

Figure 23. Trial structure of the Spatial Updating test.

There were 24 trials in total and as in the previous test, additional updates (arrows) were displayed after every 3rd trial completed. Practise procedure was as per other updating tests.

5.2.3.2 Other Measures

As well as the Context Questionnaire (described in the previous chapter), a number of other measures were administered. These were as follows:

5.2.3.2.1 **Dysexecutive Questionnaire** (Burgess et al., 1996)

The Dysexecutive Questionnaire (DEX) is a parent-report measure taken from the Behavioural Assessment of the Dysexecutive Syndrome (BADS) battery of tests (Burgess et al., 1996) (table 14). The DEX measures daily manifestations of executive function. The scoring for this measure includes a total score of executive dysfunction, as well as subscale scores. The 4 subscales are concerned with executive dysfunction as displayed through behavioural, cognitive, emotional and motivational manifestations. E.g. an item that contributes to the behaviour subscale is “They act without thinking, doing the first thing that comes to mind”, whereas an example of dysfunction as portrayed in the cognitive subscale is “They have trouble making decisions, or deciding what they want to do.” Previous analyses have shown good internal consistency for the independent rater version of this measure (this version was used in the current study) (α= .89) and good construct validity (α= .68-.80) (Hellebrekers, Winkens, Kruiper, & Van Heugten, 2017). Although this tool was initially developed to assess executive dysfunction in adults with acquired brain injury (ABI), it has been extensively used as a parent-report measure for typical and atypical child samples (Cederlund, Hagberg, & Gillberg, 2010; Roy, Allain, Roulin, Fournet, & Le Gall, 2015; Siu & Zhou, 2014; van Rijn & Swaab, 2015). Roy et al. (2015) reported good convergent validity between the DEX and indexes of the Behaviour Rating Inventory of Executive Function (BRIEF) (r= .72 - .78). However, more examinations of the psychometric properties of this measure in these populations is needed.

5.2.3.2.2 Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997)

As well as the impact supplement of the SDQ contributing to the context questionnaire, the 25-item symptom scale was used separately to assess children’s behaviour, emotional and social problems. This measure has been used recently with children aged 11-19 years who avail of Child and Adolescent Mental Health Services (CAMHS) - some of whom have diagnoses of neurodevelopmental disorders and mood disorders, (Hall et al., 2015) and has previously been validated in a large sample of typically developing children and children receiving psychiatric support, aged 5-15 years (Goodman, 1999). The “clinical caseness” classification scores were also calculated from the symptom scores to indicate whether the child’s difficulties classify them as residing in the normal, borderline or abnormal ranges of functioning.

Responses totalling between 0-13 on the total difficulties score indicated normal functioning, scores between 14-16 were indicative of the borderline range and scores between 17-40 were in the abnormal range.

5.2.3.2.3 The Parenting Scale- the Laxness and Over-reactivity subscales (Arnold et al., 1993)

The parenting scale measures parenting behaviours that have demonstrated strong associations with child behaviour problems. The measure consists of 3 subscales: laxness, which refers to inconsistent and permissive parenting, over-reactivity, which refers to harsh parenting, and verbosity, which refers to long verbal responses to behavioural issues. In the present study, only the laxness and over-reactivity subscales were utilised (table 14), as previous confirmatory factor analyses found the verbosity subscale to have low internal consistency and indeed, did not correlate with child behavioural difficulties (Salari, Terreros, & Sarkadi, 2012). This led to recommendations to use only the laxness and over-reactivity scales (Salari et al., 2012).

5.2.3.2.4 Wechsler Intelligence Scales for Children, fourth edition (WISC-IV)- Similarities and Digit Span subtests (Wechsler et al., 2003)

In order to ensure that participants had a developmental age of at least 6 years, children completed the Similarities and Digit Span subtests from the WISC-IV (table 13). These particular subtests were chosen because they allow for the possibility of administering assessments remotely (via telephone or Skype), due to the verbal stimulus-response nature of the tests, as well as providing verbal comprehension and working memory indices (Wechsler, 2004). An estimated full-scale IQ score was then calculated from the scores obtained from these subtests, using the Tellegen and Briggs formula (Sattler & Dumont, 2004; Tellegen & Briggs, 1967).

Child-report measures were also utilised in the study. These included the SAM (described in section 4.2.3.2.1.5) and a modified version of The Child Emotion Management Scale (CEMS) (Zeman, Shipman, & Penza-Clyve, 2001). However, data obtained from these tools were not used in the analyses and therefore, will not be discussed further.

5.2.4 Procedure

Ethical approval was obtained from the School of Psychology Research Ethics Committee at Queen's University, Belfast and informed consent was retrieved from all adults and assent from children before taking part in the study. Demographic information was sought, including information regarding diagnosis and medication. Face-to-face interviews with parents were conducted at their homes, in the University or at their child's school. All interviews were audio recorded for coding purposes. Two parents completed the interview over the telephone, which were also audio recorded. All parents were asked to complete the additional questionnaires online or in the session with researchers. Testing sessions with children were also administered in the above settings (with 2 children completing the battery online and the IQ tests and context questionnaire over the telephone). Two breaks were given during the battery administration so as to reduce fatigue. Most children completed all measures in one session, however, due to time restraints, this was not possible for seven of the participants, and thus two sessions were conducted for these individuals. The order of administration of the measures consisted of: completion of the context measure with parents via a semi-structured interview, parents then completed the symptom scale of the SDQ, the DEX and the Parenting Scale online. Following this, children completed the EF battery, and during the 2 breaks, the WISC subscales were administered, with the similarities subscale in the first break and the digit span in the second break.

5.2.5 Data Analysis

5.2.5.1 Predictors used in regression analyses

5.2.5.1.1 Undifferentiated EF

Undifferentiated EF is indicated by performance in all completed battery tests. This predictor variable indexes common executive ability which encompasses all 3 executive processes, while utilising the wide range of EF tests at hand (11 tests in total). Therefore, a composite score for *Undifferentiated EF* was calculated using the mean score of all standardised EF test scores (the outcome variable for each test is described in the below sections).

5.2.5.1.2 Common EF

Common EF also indexes common executive ability, but utilising only scores retrieved from completion of 3 tests, that is, 1 test per executive process. In their study, Reineberg, Andrews-Hanna, Depue, Friedman, & Banich (2015) created a composite for Common EF from performances on their 3 tests of interest: anti-saccade, category switch and keep track. Therefore, for this variable, data was used from the category switch test and keep track test. And because an anti-saccade test was not included in the battery, it was substituted with the Simon test, as the test most closely aligned to an anti-saccade test, with regards to executive properties. Where there were missing data for one or more of these tests, substitutions were made with data retrieved from the following EF tests: flanker, colour/shape and spatial updating. Again, the outcome variables for each test are described in the following sections.

5.2.5.1.3 Inhibition

Inhibition represents performance on 4 inhibition tests: Stroop, Simon, flanker and go-no/go. For the Stroop test, the outcome variable reported was conflict cost reaction time, which is the mean reaction time during conflict trials minus the mean reaction time during non-conflict trials. Error proportion during conflict trials was reported for both the Simon and Flanker tests, which represents the number of conflict trials in which the child responded incorrectly/too slow divided by the total number of conflict trials. Finally, error proportion in no/go trials was reported for the go-no/go test, which represents the number of trials in which the child incorrectly responded on a real no/go trial divided by the total number of real no/go trials. These outcome variables were selected based on previous studies which utilised a similar battery of EF tests (Friedman et al., 2008; Friedman, Miyake, Robinson, & Hewitt, 2011a; Miyake et al., 2000; Reineberg et al., 2015; Smolker et al., 2015). The inhibition composite was derived from calculating a mean score of all standardised inhibition test scores. Information on how scores were standardised are demonstrated in section 5.2.5.2.

5.2.5.1.4 Switching

Switching is a composite score calculated by performance on 4 switching tests: colour/shape, age/gender, category switch and global/local. For all switching tests, switch cost reaction time was selected as the outcome variable, which is the mean reaction time during switch trials minus the mean reaction time during non-switch trials. Again, this outcome variable was informed by previous research (Friedman et al., 2008; Miyake et al., 2000; Reineberg et al., 2015; Smolker et al., 2015) and the composite score represented a mean of standardised switch cost reaction time scores.

5.2.5.1.5 Updating

Updating is represented by a composite score which indicates performance on the 3 updating tests included in the battery: letter memory, keep track and spatial updating. The outcome variable reported for these tests is the proportion of correct responses, which is the sum of the number of updates included in trials that the child performed correctly divided by the total number of updates included in all 24 available real trials (108 updates). Like the other EF tests, the selection of the outcome variable was informed by previous research (Friedman et al., 2008; Miyake et al., 2000; Reineberg et al., 2015; Smolker et al., 2015) and the updating composite score was calculated as a mean score of all updating test performance.

5.2.5.1.6 Maladaptive ER

The ER predictor variables used in the analyses relate to maladaptive strategy usage only. As discussed in section 4.2.4.5, this measure was adapted to reduce participant demands by utilising one item per strategy, and item selection was informed by previous factor analyses. *Maladaptive ER* scores consist of scoring on all maladaptive strategy items presented in the CERQ. These maladaptive strategies can be further divided into self-focused strategies (*Self-focused ER*), which included items representing Rumination and Self-blame, and strategies that are not necessarily focused on the self (*Non-self-focused ER*), which incorporated items representing Catastrophising and Blaming Others (Bornas et al., 2012). Composite scores were calculated as the mean of standardised scores representing strategy usage.

5.2.5.2 Data cleaning

The procedure for EF test failure was as follows, failure during practice trials was deemed to be due to insufficient executive ability to pass the tests, whereas failure during introduction or tutorial trials was deemed as failure due to inattention/fatigue etc.

EF battery data was examined at a participant level, which included calculating low scores for missing or failed data and reviewing outlying scores. Failure due to inattention was not given a low score. How low scores were allocated was test-specific. For error-based inhibition tests (i.e. the flanker and Simon tests), possible scores ranged between 0 (low error rate) and 1 (high error rate), thus low scores inputted= 1. However, for the Go/no-go test, because there were no participants who scored close to 1, low scores were calculated by using 3 standard deviations above the mean (e.g. for this test, the low score= 0.923). The same method was used for reaction time-based scores, e.g. in the Stroop test and all the switching tests. As the outcome variable for all updating tests was proportion of correct responses, a low of score of 0 was allocated (again, the possible scores ranged between 0 and 1).

The total scores for all participants were then plotted and the data was reviewed for outlying scores by visually inspecting the data. During the outlier exclusion procedure, inconsistency in scoring across the tests that contribute to each EF composite was also reviewed. The following rule was applied to decide whether to include a test score or not: When reviewing scores across tests which measure the same EF (e.g. switching), an outlying score should be removed when at least 2 other test scores are markedly different from the outlying score and a similar score was not obtained in another test. And because a good outlying score is more suspicious (because this would usually indicate better performance in executive versus non-executive trials), for another test score to be deemed as similar to a good outlying value, it also has to be both good *and* outlying, otherwise the outlying score should be removed.

EF test data was then standardised by computing corresponding z scores on SPSS before calculating relevant composite scores, which were mean scores of the relevant test scores. ER data was also converted into standard scores and relevant composites were calculated.

5.2.6 Analyses

T tests and corresponding Mann-Whitney tests were conducted to compare the SC group and non-SC group on demographic information, behavioural functioning, parenting behaviour, as measured by the parent-report measures (see table 14) and EF scores, as well as self-focused and non-self-focused maladaptive ER (see table 15). Logistic regression analyses were conducted to investigate the effect of executive function, as a common entity as well as distinct processes (as illustrated in figure 12), measured through the use of the EF battery, together with maladaptive emotion regulation, on the classification of the contextually specified groups. Hierarchical regression analyses were carried out to assess which model provided the best fit. Three models were assessed: Model 1 utilised EF as a sole predictor, model 2 utilised both EF and ER as main effect predictors, and model 3 utilised both EF and ER main effects (as in model 2) but also with the addition of the EF*ER interaction. These models were compared for goodness of fit before a fitted regression analysis was conducted (Field, 2013). Equivalent analyses were also administered to predict diagnostic status (i.e. membership of the 'diagnosis' group versus the 'no diagnosis' group).

Following significant independent-samples test results, assessing the adoption of self-focused and non-self-focused maladaptive ER strategies between groups and through examining the interaction effects found in the initial analyses, it was deemed appropriate to conduct additional logistic regression analyses examining self-focused and non-self-focused strategies. Once more, these examinations took the form of hierarchical analyses as described above, before running the fitted regression analysis.

For the first analyses, the non-SC group was treated as the predicted group and the SC group as the reference group. Given the explorative nature of the analyses, this was an arbitrary decision. Beta values are reported as positive or negative. Positive betas indicate when a predictor increases, the likelihood of a person being a member of the non-SC group increases, whereas negative beta values indicate the opposite, i.e. as EF ability increases, the likelihood of a person being a member of the SC group increases. Unlike the initial analyses, given the expected link between self-focused maladaptive ER and SC group membership, the predicted group for the self-focused maladaptive ER analyses was the SC group, and the non-SC group was treated as the reference group.

To probe the interactions found, moderation analyses were conducted to test whether the conditional effect of X (EF) on Y (group membership) was significant or not at different levels of M (maladaptive ER/self-focused maladaptive ER). A moderation effect can be described as enhancing, antagonistic or buffering. Enhancing interactions are evidenced when both predictors affect the outcome in the same direction, and together create a stronger then additive effect (shown by all main effects and interactive effects as possessing coefficients of the same sign). Antagonistic interactions are evidenced when predictors have a compensatory effect on each other, particularly when one predictor is at a certain level, the importance of the other is reduced, thus signified by an interaction coefficient which is in the opposite direction to the main effect coefficients. A buffering interaction is evidenced when one predictor weakens the effect of the other. For example, as one predictor increases, the value of the other predictor is diminished, represented by main effect coefficients of opposite signs (Cohen, Cohen, West, & Aiken, 2003). To further explore the significant interactions found through the moderation analyses, simple slopes analyses were carried out with 3 levels (high, medium, low) of maladaptive ER (all) and self-focused maladaptive ER (with cut-offs at 33^{rd} and 66^{th} percentiles) (Cohen et al., 2003).

A number of assumptions have to be met to ensure the validity of logistic regression analyses, including ensuring linearity between predictors and logit of the outcome variable, little or no multicollinearity, independence of error terms, no outliers by influence, distance or leverage, and no over or under-fitting (Hosmer & Lemeshow, 2013). These assumption checks were carried out and no violations were found. Additionally, post-hoc power analyses were conducted to ensure the sample size included in each analysis was sufficient.

5.3 Results

5.3.1 Between groups analyses

In addition to the analyses pertaining to behavioural profile and emotion ratings as presented in the previous chapter, independent samples T tests were conducted to examine if there were significant differences in behavioural indices of executive dysfunction (as assessed by the DEX), behavioural symptoms (and "caseness" classification) (as measured by the SDQ symptom scale) and parenting behaviours (as measured by The Parenting Scale) between the SC and non-SC context groups.

Scores from these measures compared across SC and non-SC groups are described in Table 14.

Table 14. Group differences for the DEX, SDQ and parenting behaviour in SC group (n=40) and the non-SC group (n=23)

	SC group	Non-SC group	Statistic
	Mean (SD)	Mean (SD)	
DEX Total score	44.45 (17.99)	42.91 (17.41)	t=0.33, df=61, p=.742, d= 0.08
SDQ Total score	21.23 (6.48)	19.09 (5.75)	t=1.31, df=61, p=.195, d= 0.34
SDQ_Emotion	5.85 (2.61)	3.91 (2.43)	t=2.91, df=61, p=.005, d= 0.75
Over-reactivity	2.92 (0.96)	2.31 (0.74)	t=2.61, df=61, p=.011, d= 0.67
Laxness	3.19 (0.94)	2.91 (0.89)	t=1.19, df=61, p=.24, d= 0.30

SC group= Self-concept group; Non-SC group= Non-Self-concept group; t= t-test; d= Cohen's d

There were no significant differences between the SC group and the non-SC group in either the DEX total score and the subscales of the DEX. The clinical "caseness" bandings indicated by the total difficulties scores in the SDQ revealed the SC group consisted of 77.5% of children in the abnormal range, 12.5% in the borderline range and 10% in the normal range of functioning. In the non-SC group, 69.6% were in the abnormal range, 8.7% in the borderline and 21.7% in the normal range. However, there was no significant difference in the total difficulties score on the SDQ. Nevertheless, there was a significant difference between the groups on the emotion scale of the SDQ (see table 14), illustrating that the SC group showed more emotional symptoms, which is in line with their higher internalising behaviours score, outlined in the previous chapter. Results indicate parents from the SC group displayed significantly higher scores in over-reactive parenting in comparison to the non-SC group, yet no significant difference was found between the groups relating to lax parenting behaviour.

Although the findings relating to parenting style are of particular interest, it was ascertained that regression analyses would only address EF and ER variables. This is largely due to the theoretical rationale of the study, that is— examining whether EF and ER better predict contextual group classification than diagnostic group classification. And accordingly, the aim was not to assess whether other factors are more important in determining group classification. A further reason for not including parenting scores into the regression models pertain to the power constraints of the study.

Table 15. Group differences in EF scores and Maladaptive ER for the SC group and non-SC group

	SC group	Non-SC group	
	Mean (SD)	Mean (SD)	Statistic
Undiff EF	.27 (.75)	-.14 (.28)	t= 2.26; df= 57; p= .028, d= 0.59
Common EF	.27 (.88)	-.002 (.51)	t= 1.23; df= 57; p= .223. d= 0.33
Inhibition	.24 (.89)	-.27 (.55)	t= 2.29; df= 57; p= .025, d= 0.61
Switching	.24 (.88)	-.21 (.50)	t= 1.98; df= 52; p= .053, d= 0.55
Updating	-.13 (.79)	.06 (.93)	U= 309; p= .48, r= 0.10
Maladaptive self ER	.29 (.94)	-.49 (.87)	t= 3.30; df= 61; p= .002, d= 0.85
Maladaptive non-self ER	-.26 (.93)	.49 (.81)	t= -3.20; df= 61; p= .002, d= 0.82

Undiff EF= Undifferentiated EF; Maladaptive self ER= self-focused maladaptive ER; Maladaptive non-self ER= Maladaptive non-self-focused ER; t= t-test; U= Mann Whitney U test; d= Cohen's d; r= Cohen's effect size

T test analyses (and a corresponding Mann Whitney U test for updating, due to its skewed distribution) were conducted to examine between-group differences (SC and non-SC groups) in EF scores and maladaptive ER strategy usage. Results demonstrate there was a significant difference between the contextual groups in undifferentiated EF and inhibition scores, with higher EF scores evidenced in the SC group. However, there was no significant differences between groups in the other EF domains (see table 15). There were significant differences in the usage of maladaptive ER strategies, measured by the CERQ, between groups– with significantly more self-focused ER utilised in the SC group and significantly more non-self-focused ER utilised in the non-SC group (table 15). When considering ER strategy usage overall, findings suggest all children used maladaptive ER strategies significantly more than adaptive strategies (z= 13; p< .001). Therefore, it was ascertained that regression analyses would incorporate maladaptive ER strategies only.

5.3.2 Logistic Regression Analyses

5.3.2.1 Hierarchical Analyses for EF & Maladaptive ER (all)

Hierarchical logistic regression analyses results indicated that for all levels of EF (Undifferentiated EF, Common EF, Inhibition, Switching and Updating), Model 3 provided the best fit (table 16), as indicated by the change in chi-square between models (Field, 2013). While the inclusion of maladaptive ER in model 2 did not improve the model fit, it was ascertained that a third model was warranted as assessing the interaction between EF and ER was theoretically important (as discussed in the introduction of the current chapter, and the previous chapter). Thus, both EF and maladaptive ER main effects needed to be included in model building to do so. With this in mind, best fit was further verified by comparing the Chi squares of model 1 and 3 (Field, 2013) (these values are calculated by subtracting the 'model chi square' value of model 1 from the equivalent score in model 3. Values are in parentheses in table 17). The results suggest that differentiation of the context groups can be significantly predicted by the relationship between executive processes and maladaptive ER strategies, as demonstrated by the interaction. It was therefore ascertained that Model 3 should be employed for the fitted logistic regression analyses for all levels of EF and Maladaptive ER (all).

Table 16. Hierarchical Analyses for all levels of EF and Maladaptive ER (all)

	Model	Chi Sq	Chi Sq difference	Deviance	Cox & Snell R^2	Nagelkerke R^2
Undiff EF & Maladaptive ER (all)	Model 1	5.929*		68.221	0.096	0.134
	Model 2	0.810		67.411	0.108	0.151
	Model 3	6.457*	(7.267)	60.955	0.200	0.280
Common EF & Maladaptive ER (all)	Model 1	1.627		72.524	0.027	0.038
	Model 2	0.450		72.074	0.035	0.048
	Model 3	7.905**	(8.355)	64.169	0.156	0.218
Inhibition & Maladaptive ER (all)	Model 1	5.561*		68.589	0.090	0.126
	Model 2	0.456		68.132	0.097	0.136
	Model 3	6.511*	(6.968)	61.621	0.191	0.267
Switching & Maladaptive ER (all)	Model 1	4.256*		64.487	0.076	0.105
	Model 2	0.914		63.573	0.091	0.127
	Model 3	12.291***	(13.205)	51.282	0.276	0.384

Updating & Maladaptive ER (all)	Model 1	0.787		61.771	0.017	0.023
	Model 2	2.830		58.941	0.074	0.101
	Model 3	4.062*	(6.892)	54.879	0.151	0.205

Model 1: EF as main effect; Model 2: EF and Maladaptive ER (all) as main effects; Model 3: EF and Maladaptive ER (all) as main effects and EF*Mal ER (all) interaction; Undiff EF= Undifferentiated EF; * =p < .05; **= p< .01; ***= p< 0.001

5.3.2.2 Fitted Logistic Regression Models

5.3.2.2.1 Undifferentiated EF and Maladaptive ER (all)

Both Undifferentiated EF and Undifferentiated EF*Mal ER (all) were significant predictors in determining whether a participant will be classified as a member of the non-self-concept group or not (B= -2.104, p= .030; B= 3.003, p= .038). Lower undifferentiated EF increases the likelihood of being classified into the non-SC group, but increases in maladaptive ER counteract this effect and make it more likely for a child to be classified into the SC group (table 17). Indeed, the interaction demonstrated suggests that as maladaptive ER increases, the importance of Undifferentiated EF on group classification is weakened (antagonistic interaction). No moderation was found. A post-hoc power calculation revealed that the analysis had a power of 0.999.

5.3.2.2.2 Common EF and Maladaptive ER (all)

Only the Common EF*Mal ER (all) interaction significantly contributed to the differentiation of the groups (B= 1.802, p= .026). Like Undifferentiated EF, lower EF increases the likelihood of being a member of the non-SC group, however, increases in maladaptive ER counteracts this effect and increases the likelihood of a child being a member of the SC group. Again, as maladaptive ER increases, the influence of Common EF on group membership is lessened (antagonistic interaction). No significant results were found in the moderation analyses. A post-hoc power calculation revealed that the analysis had a power of 0.995.

5.3.2.2.3 Inhibition and Maladaptive ER (all)

Both Inhibition and Inhibition*Mal ER (all) were significant predictors in determining whether a participant will be classified as a member of the non-SC group or not (B= -1.321, p= .031; B= 1.596, p= .032). Lower inhibition alone increases the likelihood of being classified into the non-SC group, however as maladaptive ER increases, so does the likelihood of being in the SC group (table 17). Again, the antagonistic interaction found indicates that as maladaptive ER increases, the effect of inhibition on the discrimination between groups decreases. No moderation was found. A post-hoc power calculation revealed that the analysis had a power of 0.977.

5.3.2.2.4 Switching and Maladaptive ER (all)

Only the interaction between switching and maladaptive ER strategies was found to be significantly contributing to the prediction of group membership (B= 3.074, p= .010). As demonstrated in the previous analyses, membership of the non-SC group, rather than the SC group, is predicted by having poorer EF, which is then counteracted by increases in maladaptive ER which increases the likelihood of SC group membership- this is again true for the switching analyses (table 17). Moderation analyses were conducted to test whether the conditional effect of switching on group membership was significant or not at different levels of maladaptive ER. Moderation was found (B= -2.697; p=.036) and the results indicate that the relationship between switching and group membership depends on maladaptive ER, specifically at low levels of maladaptive ER (p=.027), suggesting that as maladaptive ER increases, effect of switching on group classification is weakened. A post-hoc power calculation revealed that the analysis had a power of 0.999.

5.3.2.2.5 Updating and Maladaptive ER (all)

Although model 3 provided the best fit for the updating model as indicated by the model fitting analyses, none of the predictors in the fitted model reached significance, thus they did not significantly contribute to the differentiation of the groups (table 17). Nevertheless, it is important to note that unlike the other EF models, the results pertaining to updating and maladaptive ER suggest that higher updating increases the likelihood of being classified into the non-SC group but as maladaptive ER increases, so does the likelihood of being classified into the SC group. A post-hoc power calculation revealed that the analysis had low power of 0.696.

Table 17. Fitted Logistic Regression Analyses for all EF levels & Maladaptive ER (all)

Model	Predictors	B	Std error	z	p	OR	CI (lower)	CI (upper)
Undiff EF model	Undiff EF	-2.104	.968	4.722	.030*	.122	.018	.814
	Maladaptive ER (all)	-.244	.373	.426	.514	.784	.377	1.628
	Undiff EF*Mal ER (all)	3.003	1.444	4.322	.038*	20.140	1.187	341.607
Common EF model	Common EF	-.839	.540	2.416	.120	.432	.150	1.245
	Maladaptive ER (all)	-.480	.377	1.620	.203	.619	.295	1.296
	Common EF*Mal ER (all)	1.802	.810	4.951	.026*	6.065	1.239	29.673
Inhibition model	Inhibition	-1.321	.612	4.661	.031*	.267	.080	.885
	Maladaptive ER (all)	-.119	.371	.103	.749	.888	.429	1.836
	Inhibition*Mal ER (all)	1.596	.743	4.615	.032*	4.935	1.150	21.177

Switching model	Switching	-1.243	.714	3.031	.082	.289	.071	1.169
	Maladaptive ER (all)	-.246	.449	.301	.583	.782	.324	1.884
	Switching*Mal ER (all)	3.074	1.188	6.699	.010*	21.621	2.109	221.681
Updating model	Updating	.271	.433	.391	.532	1.311	.561	3.064
	Maladaptive ER (all)	-.903	.479	3.552	.059	.405	.159	1.037
	Updating*Mal ER (all)	-.991	.575	2.964	.085	.371	.120	1.147

Undiff EF= Undifferentiated EF; Mal ER= Maladaptive ER; * =p < .05

5.3.2.3 Analyses predicting Diagnostic Status

Additional logistic regression analyses were conducted to explore whether EF and Maladaptive ER strategies can significantly predict the diagnostic status of participants (i.e. membership of the ‘diagnosis’ group (n=42) versus the ‘no diagnosis’ group (n=21)). These investigations resulted in no significant models for any levels of EF with Maladaptive ER (all) (with results ranging from B= .013 to B= .332; p= .492 to p= .973). These findings suggest that unlike the contextually specified groups, EF and Maladaptive ER cannot be considered to significantly differentiate groups categorised by diagnosis.

5.3.2.4 EF & Self-focused ER/Non-Self-focused ER

Further logistic regression analyses were carried out to assess all levels of EF and self-focused and non-self-focused maladaptive ER. Hierarchical analyses were constructed in a similar format as the previous analyses, with model 1 assessing EF as a sole predictor, model 2 assessing EF and Self-focused ER *or* Non-self-focused ER as main effect predictors, and model 3 assessing both main effects (as in model 2) but with the addition of the EF*ER interaction. However, due to the expected significant difference in the adoption of self-focused and non-self-focused strategies between the two context groups ($t(61) = 3.300$, $p = .002$; $t(61) = -3.203$, $p = .002$), it was anticipated that model 2 would prove the best fitting model. Yet, following the initial regression analyses, the relationship between EF and self-focused or non-self-focused ER became the main concern, thus the significance of the EF*ER interaction was the focus of these analyses. Again, moderation and simple slopes analyses were also conducted.

Hierarchical analysis results for EF and Self-focused ER suggested that there was no significant interaction between Undifferentiated EF, Common EF or Inhibition and Self-focused ER. However, corresponding significant results were found for Switching and Updating (table 18), suggesting that the relationship between switching and updating with self-focused maladaptive ER strategies influence context group membership.

5.3.2.4.1 Switching and Self-focused ER

In the fitted regression, both Self-focused ER and the Switching*Self-focused ER interaction were found to be significant predictors for contextual group membership (B= 1.396, p= .017; B= -2.707, p= .042). As switching ability decreases, the likelihood of being classified into the non-SC group increases but increases in self-focused maladaptive ER counteract this effect and make it more likely for children to be classified in the SC group (table 19). Like the previous analyses assessing switching with maladaptive ER (all) self-focused maladaptive ER was found to moderate (B= 2.707; p= .042) the relationship between switching and group membership, particularly at low levels of self-focused maladaptive ER (p= .014). And as the conditional effect of switching on group classification is significant only at low levels of self-maladaptive ER, this suggests that as self-focused maladaptive ER increases, the importance of switching on contextual group membership is lessened. A post-hoc power calculation revealed that the analysis had a power of 0.950.

5.3.2.4.2 Updating and Self-focused ER

Results suggest that both Self-focused ER and the Updating*Self-focused ER interaction were significant predictors in determining whether a participant will be classified as a member of the SC group or not (B= 2.370, p= .013; B= 2.743, p= .038). Findings indicate that as updating ability decreases, the likelihood of being classified in the SC group increases and increases in self-focused maladaptive ER further increase the likelihood of being classified in the SC group (table 19). In other words, high levels of self-focused maladaptive ER are further exacerbated by low updating ability, predicting impairment in SC contexts. Furthermore, self-focused maladaptive ER was found to moderate (B= -2.743; p= .039) the relationship between updating and group membership, particularly at low levels of self-focused maladaptive ER (p= .043). These regression analyses showed a buffering interaction, indicating that as self-focused maladaptive ER increases, the effect of updating on group classification is diminished. A post-hoc power calculation revealed that the analysis had a power of 0.979.

Table 18. Hierarchical Analyses for Switching & Self-focused ER and Updating & Self-focused ER

	Model 1	Model 2	Model 3
	Beta (OR)	Beta (OR)	Beta (OR)
Switching	1.170* (3.223)	1.486* (4.421)	.829 (2.291)
Self-focused ER	-	1.387** (4.004)	1.396* (4.040)
Switching*Self-focused ER	-	-	-2.707* (.067)
Updating	-.269 (.764)	-.329 (.720)	-.243 (.785)
Self-focused ER	-	1.171** (3.224)	2.370* (10.702)
Updating*Self-focused ER	-	-	2.743* (15.527)

* =p < .05; **= p< .01

Table 19. Fitted Logistic Regression Analyses for Switching & Self-focused ER and Updating & Self-focused ER

Model	Predictors	B	Std error	z	p	OR	CI (lower)	CI (upper)
Switching model	Switching	0.829	0.812	1.043	0.307	2.291	0.467	11.241
	Self-focused ER	1.396	0.587	5.665	0.017*	4.040	1.279	12.754
	Switching* Self-focused ER	-2.707	1.330	4.139	0.042*	0.067	0.005	0.906
Updating model	Updating	-0.243	0.701	0.120	0.729	0.785	0.199	3.100
	Self-focused ER	2.370	0.959	6.107	0.013*	10.702	1.633	70.134
	Updating* Self-focused ER	2.743	1.325	4.283	0.038*	15.527	1.156	208.516

* =p < .05

Finally, results from the logistic regression analyses pertaining to non-self-focused ER suggested that the interaction between EF and non-self-focused ER strategies provided no significant contribution to the differentiation of the context groups, for all levels of EF. Therefore, no further investigations were continued for analyses concerning non-self-focused ER.

5.4 Discussion

Analyses were conducted to examine the contribution of EF and maladaptive ER strategy usage in predicting contextual group classification, that is children most affected by contexts that threaten their self-concept, and children most affected by contexts that do not threaten their self-concept. Findings indicate that EF (at multiple levels- common EF, inhibition and switching) and maladaptive ER significantly interact to discriminate groups, suggesting differential control process profiles are apparent in the two groups. Importantly, no significant corresponding results were reported when children were separated by diagnostic group (i.e. having a diagnosis or not) for any of the analyses. Thus, these results support our hypothesis that contextual interference bears more clinical importance on control process deficits and in turn, maladaptive behavioural responses, than diagnostic presentation. Further, these results suggest that EF and ER can be used as transdiagnostic markers in the expression of internalising and externalising behaviour in children across the diagnostic spectrum. These findings are in line with previous work that propose EF and ER deficits are evidenced across diagnoses (Aldao, 2016; Fernandez et al., 2016; Kofler et al., 2018; Lima et al., 2018; Snyder et al., 2015) and thus, extends the transdiagnostic perspective in developmental behavioural impairment research (Franklin et al., 2015). Not only do these results show that emotionally salient contextual information impacts control processing, as indicated by previous research (Evans & Rothbart, 2009; Ibañez & Manes, 2012; Mazefsky et al., 2012; Pessoa, 2009). But the current findings suggest that this contextual information exerts distinct demands on EF and ER processing, resulting in specific profiles of control process deficit, which cannot be explained by diagnostic presentation.

These distinct control process profiles in the context groups are evidenced in the results, with children in the non-SC group displaying poorer EF abilities overall (Undifferentiated EF, Common EF, inhibition, switching). However, when high levels of maladaptive ER were engaged with, classification into the SC group is likely. Therefore, as maladaptive ER increases, the importance of EF on differentiating the contextual groups is lessened. This indicates that increased engagement in maladaptive ER can negatively interfere with EF performance. And as descriptive analyses showed high maladaptive ER across the whole sample, these results led the researchers to look more closely at the type of maladaptive strategies utilised.

When the strategies were separated into self-focused maladaptive ER (rumination and self-blame) and non-self-focused maladaptive ER (catastrophising and blaming others), results demonstrated significantly higher scores for the SC group in self-focused strategies and significantly higher scores in non-self-focused strategies in the non-SC group. Therefore, further analyses to investigate how EF interacts with these distinct maladaptive strategies in the classification of children into the contextual groups followed. Results revealed better switching in the SC group. Yet, notably, the importance of this increased switching ability was weakened by high self-focused maladaptive ER. This interaction between switching and self-focused ER suggests that increased self-focused maladaptive ER negatively interferes with the reported better switching capability in the SC group. Therefore, these findings parallel those found when all maladaptive ER strategies were considered in the previous switching analyses.

The first analyses which assessed updating and maladaptive ER in predicting contextual group membership did not result in significant findings, and these may be due to the under-powered nature of this dataset. However, of note was that updating was more impaired in the SC group in comparison to the non-SC group, while better performance of the other executive processes was reported in this group. Therefore, it was felt further examinations of updating and self-focused maladaptive ER was warranted.

In further updating analyses, as well as showing poorer updating performance in the SC group in comparison to the non-SC group, results indicate self-focused maladaptive ER moderates the relationship between updating and group membership, which is significant at low levels of self-focused maladaptive ER. These results suggest that high self-focused ER as evidenced in SC contexts is further exacerbated by poor updating. Therefore, findings pertaining to updating impairment in the SC group, despite these children attaining higher scores in other EF domains, extends our understanding of the role of updating on specific contextual impairment.

It is interesting to note that the results indicated that undifferentiated EF, which represents common executive ability, and inhibition showed similar patterns across many of the analyses. Both undifferentiated EF and inhibition scores were significantly better in the SC group, in comparison to the non-SC group. And accordingly, undifferentiated EF and inhibition were significant sole predictors in the classification of the contextual groups— a finding not evident for the other EF predictors. Further, unlike switching and updating, undifferentiated EF, common EF and inhibition did not significantly interact with self-focused ER. Perhaps this may be, in part, due to the better performance of undifferentiated EF and inhibition evidenced in the SC group. Therefore, unlike other executive processes, the enhanced EF ability in these domains are not affected by the increased self-focused maladaptive ER in this group. Furthermore, the patterns of results pertaining to the similarity in common executive (as demonstrated by undifferentiated EF) and inhibition, and differential results relating to the other executive processes provide support for the structure of EF at a neural level as evidenced in chapter 2. That is, a common overarching executive process that encompasses inhibition engagement, and dissociative switching and updating process-specific capacities. What is surprising is the possible contribution of this EF structure in contextual impairment and the adoption of specific emotion regulatory skills and thus, further investigation into these relationships is warranted.

5.4.1 Switching and self-focused maladaptive ER interaction

The results of the current study suggest that children in the non-SC group were more impaired in their switching ability than children in the SC group. Further, the antagonistic interaction found indicates that increased engagement in self-focused maladaptive ER lessens the importance of this increased switching ability in identifying group members. While previous research reports that switching deficits are associated with increased self-focused maladaptive strategies (Davis & Nolen-Hoeksema, 2000; De Lissnyder et al., 2010; Whitmer & Banich, 2007), many have found this effect when individuals switch between personally relevant information (Beckwé et al., 2013; Rochat et al., 2012). Whereas, in the current study the switching tests required children to switch between neutral task sets only. Therefore, it is possible that increased self-focused maladaptive ER may not be explained by neutral switching differences. However, incorporating self-relevant contextual content in switching tests may further elucidate how switching and self-focused ER are linked in this population.

As previously discussed, studies have found direct links between switching deficits in children who display behavioural difficulties following specific contextual demands. Indeed, Woodcock, Oliver, & Humphreys (2011) found such an effect following a change in routine in children with Prader-Willi Syndrome, which was explained by an impairment in switching. Interestingly, in the current study, the situation identified in this past research- a change to routine- would be categorised as a non-SC context. Notably, some participants in the current study reported comparable contextual descriptions as their most negatively impacting situation, and accordingly, links between switching deficits and the negative impact of changes to routines may contribute to the poorer switching abilities evidenced by the present non-SC group. Additionally, in line with the previous paragraph, perhaps measuring neutral switching is more indicative of switching impairments in situations whereby restraints are enforced from an external source (as in non-SC contexts), as opposed to contexts which may be perceived as self-attributed or self-threatening.

5.4.2 Updating and self-focused maladaptive ER interaction

Unlike the other executive processes, updating was impaired in children who were most negatively affected by situations which threaten their self-concept. And results indicate that increased self-focused maladaptive ER, as evidenced in the SC group, is further exacerbated by updating impairment. This finding is in line with the theoretical position discussed in sections 4.4.2 and 5.1.2, which made links between the current investigation and the appraisal stages presented by the Scherer Component Process model (CPM) (Scherer, 2009). It was suggested it may be informative to consider the normative significance appraisal stage detailed in this model in the assessment of SC contextual impairment. And as the CPM model proposes the evaluative stages are recursively processed, it is possible such processing bears some semblance to updating demands. Therefore, it was suggested updating ability may be impaired in the SC group. Indeed, the current findings support this position, particularly in light of the relationship found between increased self-focused ER and updating. However, findings show this theoretical link cannot be made with regards to switching, as was also previously suggested in section 5.1.2.

As previously discussed, there is existing evidence which implicates updating deficits in the engagement with self-focused maladaptive strategies. Of note, Pe et al. (2013) found a moderating effect of updating on rumination and negative affect. Specifically, they reported that high updating ability acts as a protective factor against high arousal negative emotions when ruminating. Although the updating information in this study incorporated emotional content, unlike the current study which utilised neutral content, evidence suggests that general increased updating ability may promote flexibility away from prolonged negative self-referential thinking, indicative of the self-focused maladaptive strategies assessed in the current study. However, questions remain regarding why the link between updating impairment and increased self-focused maladaptive ER is not confined to updating self-relevant emotional information. Therefore, further examination of this link utilising self-referential emotional updating is needed.

When considering current findings pertaining to all levels of EF, it is clear that maladaptive ER undermines the importance of these executive processes in the discrimination of the contextually defined behavioural groups. The interactions found between self-focused ER and updating and switching in particular, suggest distinct profiles of impairment which may help to explain the expression of clinically relevant behaviour in specific emotionally salient contexts.

5.4.3 Limitations

An important consideration when examining the findings of the current study is the argument regarding the development of ER in children. There is not a clear consensus as to when children are able to efficiently use adaptive ER strategies. The authors of the CERQ (Garnefski et al., 2007) reported that efficient use of adaptive ER strategies is usually acquired at approximately 8 to 9 years old, therefore, it is possible we may have to question the appropriateness of this measure for the younger children in our sample. Therefore, although we expected our sample to use more maladaptive strategies than adaptive strategies - given their behavioural difficulties - the younger age of some of the children may have further exacerbated the low score in adaptive ER. Additionally, while this study provides a novel way of assessing ER strategy usage in response to emotionally salient contexts, the reduced use of items pertaining to this information and thus, ultimately utilising a measure that has not been previously validated, may not present a complete picture of the extent of ER engagement. Therefore, the findings must be treated with a degree of caution. And importantly, further examination of ER should adopt a more detailed exploration of ER strategy usage in this population. On the other hand, the EF battery was a well-informed and considerably comprehensive tool. However, given the overall goal of this work was to assess the contribution of EF and ER in behaviour difficulties following differential emotionally salient contexts, perhaps eliciting emotional arousal during engagement in executive tests could further demonstrate the interference of emotional salience on EF performance.

Another possible limitation pertains to the difference in the contextual group sample sizes, as the number of children in the non-SC group was considerably smaller. However, given the rationale and methodology of the current study, this was not something researchers could control, as the groupings were determined by the contextual information provided by parents during testing. Therefore, prior to testing, an overall sample size estimate was the most appropriate alternative.

The study also included a wide age range and intellectual ability, which could of course have an effect on EF performance. However, the estimated IQ score mean of the sample was representative of the population and there was no significant difference in age and estimated IQ between groups. Lastly, it became apparent during testing that the child-report data, particularly in relation to the emotional salience ratings and the ER scores, may have been influenced by social desirability issues, limiting its validity. Therefore, it was determined that the corresponding data obtained from parents would provide a more valid account of the clinical presentation shown by the children.

It is important to consider the classification of children into diagnostic groups for the purposes of statistical analyses, given the transdiagnostic perspective promoted throughout the work. The wide ranges in diagnoses evident in the diagnostic group suggests a high level of heterogeneity and therefore poses questions for this use, particularly when compared to a no diagnosis group. While the inclusion of such an analysis works in opposition to the endeavours of the current research, it was decided its addition could be utilised solely as an illustration of the importance of considering how underlying processes, such as EF and ER present across the diagnostic spectrum. And using comparable diagnostic groups only, as is traditionally utilised in clinical developmental research, limits the examination of these putative processes. Further, it is felt these comparable analyses demonstrate the need for clinical intervention with children who do not fall into a developmental diagnostic group but exhibit considerable behavioural and/or emotional difficulties.

5.4.4 Implications

As highlighted previously, further efforts to understand the relationship between switching and updating and self-focused maladaptive ER may benefit from eliciting self-referential emotional responses during executive test performance (Wagner et al., 2013). It is hoped this would help to elucidate real-world links between maladaptive self-focused processes and executive capability in contexts which place increased self-salient demands on such control processes, and thus, inform on clinical intervention. As well as encouraging the improvement of emotion regulatory skills in therapeutic practice, an important consideration for clinicians may be an increased focus in training executive processes- particularly updating and switching (Denson, 2015; Juarascio, Manasse, Espel, Kerrigan, & Forman, 2015; Swainston & Derakshan, 2018; Vinogradov, Fisher, & De Villers-Sidani, 2012). Given that therapeutic models aim to help individuals to adjust their habitual thinking patterns and/or behaviour responses, it is not difficult to see how increased executive ability and associated cognitive flexibility would aid greater therapeutic adherence and enhanced clinical outcomes (Juarascio et al., 2015). Therefore, the joint application of ER and EF improvement, together with increased consideration of the specific contextual demands placed on these processes by the environment, may provide better insight into how best to facilitate behaviour change in this population.

5.4.5 Conclusion

The current findings support the view that contextual emotional salience has the ability to negatively impact cognitive and emotional processes which allow a person to control their behaviour. Moreover, results indicate that in comparison to diagnostic presentation, specific contextual impairments- particularly in situations that threaten the self-concept- better inform control process deficits and their role in behaviour difficulties. Indeed, the current findings support the heterogeneity of control process profiles across diagnostic groups and thus support transdiagnostic approaches to behavioural intervention. Further examination is needed, which uses an integrated approach to identify cognitive and emotional control profiles (particularly incorporating switching and updating with self-focused maladaptive ER) through the assessment of contextual demands in children with internalising and externalising behaviour. Through bridging the gap between neurocognitive and emotional processes, maladaptive behavioural responses and wider contextual demands, advancement in how to prevent clinical levels of behaviour difficulties in children may be achieved.

Chapter 6

6.0 General Discussion

6.1 Aims of Thesis

The aims of this thesis can be divided into two clear sections. The first section pertains to examining the structure of EF in typical development, by assessing neural activation via fMRI. Given the paucity of fMRI meta-analytic investigation into how EF is structured in development and the specific applicability of the integrated approach (which proposes an EF structure representative of partially common and partially separable processes) to typical development, it was felt this work was potentially informative before turning my attention to the effect of EF in clinically relevant behaviour, indicative of atypical development. Alongside this meta-analysis, the neural impact of the non-executive demands comprised in EF tasks was assessed. This work informed the development of a new measurement tool that aims to minimise the confounding impact of non-executive demands on EF measurement in individuals with NDDs. The second section of the thesis considers the role of EF in maladaptive behaviour and specifically, how emotionally salient contextual factors can affect this relationship. As previous research has found an important link between ER and the expression of behavioural difficulties, and a relationship with EF and maladaptive ER was also assessed. As this thesis explores neural substrates of EF processes and also aims to assess how such executive processes can be attributed to the expression of behaviour difficulties in specific contexts, a transdiagnostic perspective was employed. It was anticipated that this approach would contribute to the elucidation of identifying aberrant processes which warrant clinical attention. Further, this work hoped to identify specific profiles of deficit in EF and ER which explain impairment in specific emotionally salient contexts, and thus, increase potential for future intervention.

6.2 General Findings

6.2.1 The structure of EF in typical development- at a neural level

Chapter 2 presented a meta-analysis of fMRI data of children and adolescents engaging in EF tasks. As discussed in this chapter, there has been much debate regarding the structure of EF in both the adult and child literature, with particular inconsistency portrayed in the development of EF in childhood. A model addressing EF structure in adults, which has drawn extensive support, proposes an integrative structure consisting of common and distinct components of EF (Miyake et al., 2000). This model has been applied to child samples, yet, no thorough investigation into how EF is structured in development at a neural level had been carried out. Therefore, the current meta-analysis hoped to resolve this fundamental question.

Findings showed a comparative structure in children that had been reported in adults, with both common and dissociative processes depicted by shared and non-shared neural activation. Activity relating to a common dimension across the executive processes (the common executive) and executive process-specific activation were found. In line with the integrative model in adults, no inhibition-specific activation was reported, indicating that inhibition may not separable to the common executive. Furthermore, when data pertaining to child-only (6 -12 years) activation was compared to data pertaining to both the child and adolescent sample, no process-specific activation was demonstrated in the child-only group. These findings suggest that updating-specific and switching-specific processes may only delineate from the common executive later in childhood. However, it must be noted there was a lack of switching studies incorporated in the data-set, therefore, indications referring to the switching activity must be treated with caution. Overall, these results suggest a new systematic developmental model be proposed, which illustrates this integrative structure. Further, the findings call for more consideration of process-specific components in EF measurement in children.

While there were notable merits of this work, it must be considered that choosing age cut-offs that were essentially arbitrary may have important implications on the findings. Comparing a child only group that is represented by children aged 6 to 12 years with the total sample, resulting in inferences about the emergence of dissociative processes, is questionable. Because of these broad age ranges, one cannot tell when in the adolescent period, separable processes are evident. Therefore, if studies were allowing, it may be more informative to break down the age ranges further in future work. A possibility for uncovering specifics about the evolving structure of EF during development, may be creating multiple variations of groups, with incrementally different age cut offs e.g. one group may be between 8 to 11 years and the next group, may be between 8 years 6 months to 11 months 6 months. It is possible this method could reveal the precise periods of delineation that could signify important intervals for intervention.

6.2.2 Non-executive demands in EF task performance- at a neural level

The brain region data reported in the meta-analysis, as illustrated in chapter 2, demonstrated that idiosyncratic non-executive components of EF tasks may be contributing to the neural activation presented. Indeed, non-executive demands embedded in EF tasks is a well-documented issue, particularly in light of the antagonistic influence such demands exert on accurate EF assessment. For that reason, a second meta-analysis utilising the same participant data as the first meta-analysis, was conducted. This study however addressed the stimuli-type and test-type components of the activation in the child and adolescent sample. It was hoped that the results would indicate which stimuli modes (across all EF tasks) and inhibition test-types contributed the most to executive activation. The stimuli-type findings show that stimuli which included letters recruited the greatest proportion of common executive and updating activation. This was followed by stimuli displaying arrow, spatial and picture stimuli respectively. The inhibition test-type analyses resulted in a ranking of inhibition tests utilised across studies, with regard to their contribution to executive activity. The findings show that flanker tests demonstrated the greatest amount of neural activation, followed by Stroop, go-no/go, Simon, anti-saccade and stop tests. Moreover, the results of this study contributed to the development of a new online EF battery of tests, which in turn aimed to overcome some limitations of EF assessment, as discussed in chapter 3, including the task-impurity problem. The battery was then administered with children in the subsequent study described in chapters 4 and 5.

Reflecting on this study, it is important to consider the assumption taken in this work pertaining to the stance that greater activation is indicative of better measurement of

EF. As discussed in section 3.1.3, the basis of this assumption lies in the belief that neural activity that is shared across multiple tests reflects EF activation and it is unlikely to reflect non-executive noise facilitated by idiosyncratic test-specific interference. Therefore, this work suggests that letter stimuli does not interfere in the measurement of executive processing as much as other stimuli and thus, provides a good foundation for test design. Although this assumption is perfectly reasonable, it is important to test this premise in the future. Another option may be to create identical test paradigms, with interchangeable stimuli or response modes that could allow precise examination of the effect of discrete non-executive task changes on neural activation.

6.2.3 Specification of clinically relevant contexts

Chapter 4 presents the first objective of the IN CONTROL study, which concerns the identification of emotionally salient contexts or situations which elicit clinically relevant behaviour in children across the diagnostic spectrum. This was achieved through the development of a new measurement tool which was administered during semi-structured interviews with parents of children with behavioural difficulties. The tool afforded parents the opportunity to describe a situation which they believe to be the most negatively impacting to their child and which typically results in clinically relevant maladaptive behaviour responses. As well as this, information relating to the profile of the behaviour expressed and the clinical impact of the behaviour was obtained. The data was then analysed and a clear differentiation was made between the contexts illustrated by parents, which resulted in the formation of two groups: 1) children who were most affected by contexts that threaten their self-concept (SC group), and 2) children who were most affected by contexts that do not threaten their self-concept (Non-SC group).

Findings show an even diagnostic spread of children between the groups, suggesting the contextual impairment was not reflective of a specific diagnostic group. The diagnostic groups included were separated into groups consisting of children with no diagnosis, children with ASD and children with a genetic syndrome (i.e. Downs Syndrome, Neurofibromatosis (type 1), Foetal Alcohol Spectrum Disorder (FASD). Further, results indicated that comparable clinical levels of behaviour were shown across the groups, as well as comparative emotion ratings for the contexts in question, suggesting the contexts were of similar emotional salience across the whole sample. Moreover, the results showed that although children in the SC group displayed more internalising behaviour and children in the non-SC group exhibited more externalising, most children across both groups presented with a mixed behaviour profile, that is, expressing both internalising and externalising behaviours. The results of this work suggest the distinction made between the two groups is of clinical relevance. And as previous research, discussed in chapter 4, indicates the influence of emotionally salient contextual information on control processes, such as EF and ER, this work provides a basis for further investigation into whether specific profiles of deficit in these process domains can be identified between the two groups.

When reviewing this study, it is important to consider that the contexts identified may have been influenced by the context measure developed in this work. As outlined in section 4.4.4, it is possible parents may have been directed in their responses by the presentation of prior selected examples of emotionally salient situations. Another consideration is in the classification of children into the context groupings when the ranking system used indicated many children were still impacted by contexts that were largely reflective of the other contextual group. Another related issue to consider is the specificity of the contextual impairments identified in the research. While the contexts were extracted from qualitative parent data and were subsequently operationally defined, it is possible other meaningful distinctions between the descriptions could have been detected. In other words, instead of discriminating children in terms of the impact of the situation on their self-concept, there may be other important aspects embedded in the contexts that constituted group classification.

6.2.4 The identification of distinct profiles of EF/ER deficit

Chapter 5 considers the relationship between EF and the use of maladaptive ER strategies (including specifically self-focused maladaptive ER strategies, rumination and self-blame) in contextual impairment, as established in the first part of the study (discussed in chapter 4). Findings indicated significant interactions between EF (at multiple levels- common EF, inhibition and switching) and maladaptive ER strategies in discriminating the contextually specified groups, suggesting there are distinct control process profiles between the groups. Comparative interactions were found between switching and updating respectively, and the use of self-focused maladaptive ER. The profile that differentiated the SC group (from the non-SC group) included better switching ability, yet the engagement of high self-focused maladaptive ER weakened this switching influence.

Results pertaining to updating and self-focused maladaptive ER indicated poorer updating ability in the SC group, which is at odds with the performance of this group in the other EF domains. As well as this, results showed self-focused maladaptive ER moderated the relationship between updating and group classification, which is significant at low levels of self-focused maladaptive ER. These findings suggest that high self-focused ER acts as a risk factor for SC contextual impairment, and the interaction found suggests low updating ability, as evidenced in this group, may increase the employment of such maladaptive strategies. The suggestion that updating may further exacerbate the recruitment of self-focused maladaptive strategies, and that this relationship is determined by the type of contextual impairment presented, is an intriguing finding. Indeed, this finding lends support for the idea that specific contextual demands can interfere with control processes that influence maladaptive behaviour responses.

6.2.5 Evidence for transdiagnostic control process profiles

Importantly, in line with our hypotheses, comparative analyses demonstrated no significant results between diagnostic groups. Thus, it could be argued that specific contextual impairments may provide a better explanation for the expression of differential control process profiles and resulting maladaptive behaviour, than diagnosis. Accordingly, the findings contribute to the wider transdiagnostic approach by assessing the role of cognitive substrates in the expression of clinically relevant presentations across diagnostic groups.

6.3 Limitations

Limitations of the specific studies carried out in this thesis have been discussed in the relevant chapters. However, wider limitations of the perspectives taken in the work as a whole will be presented here.

6.3.1 A Focused Approach

The focus of investigation in this thesis is on how EF influences behaviour and how contextually specified emotional salience impacts this relationship between EF and behaviour, as well as ER. However, it must be considered that additional processes, other than EF, exert control on maladaptive behaviour responses. Our investigations allowed us to adopt a focused approach to assessing the EF-behaviour relationship, and while there are many merits to this, the focus limits our ability to identify additional pathways which may explain behaviour difficulties in the putative contexts. Indeed, there are a multitude of different processes which play a role in maladaptive behaviour, both internalising and externalising. Examples include molecular and genetic mechanisms, which are particularly evident for clinical populations, as demonstrated in our sample. Furthermore, it is possible there are other explanatory variables for why a child would be a member of one contextual group over another. And these variables may be due to circumstances outside of the individual, e.g. family dynamics, wider social and environmental factors, cultural norms, parenting etc. (Delvecchio et al., 2014; Raval, Daga, Raval, & Panchal, 2016; Raval, Li, Deo, & Hu, 2018; Scharf & Goldner, 2018).

6.3.2 Application of EF to real world

An assumption of the research considers EF, as measured in the study, to be applicable to the behaviour responses and the contextual factors illustrated in the IN CONTROL study. However, there is an argument in the literature that proposes cool EF, as assessed by our EF battery, is not representative of the executive processes employed in emotional and clinically relevant everyday situations, indicative of the contexts considered in our research (Burgess et al., 2006). This argument must be acknowledged when considering this work. However, as discussed previously, there is a theoretical basis and certainly, previous evidence, that suggests cool EF as assessed in this work, does have a role to play in such behaviours and contexts.

6.3.3 Lack of age-related investigation

The findings of the meta-analysis as demonstrated in chapter 2 highlights the importance of age-related changes in the structure of EF throughout development. And as our argument considers EF to be a contributory element to the expression of behaviour difficulties in children, as well as the impact of context on specific EF skill, it would have been beneficial to assess if the dynamics of this relationship differ at distinct developmental stages. The prospect of further elucidating the role of contextual impact on EF across development is intriguing, as one might expect there to be a meaningful interaction between contextual factors and age. However, to facilitate this, the inclusion of adolescents without an ID is crucial, yet our EF battery was designed for children with a developmental age of up to 12 years only. Furthermore, one has to question the validity of estimating developmental age for the children with intellectual disability, and estimating the appropriate age cut-offs or inclusion.

Another consideration pertains to the inclusion of children aged 6-12 years old in the sample for the IN CONTROL study, when the meta-analysis presented in chapter 2 indicated no process-specific activation in this age group. And while the battery developed from this work aims to assess EF in this developmental period, it is not yet clear how discernible process-specific deficits are measurable at this age. Accordingly, it is imperative that future work into the structure of EF deficits at this developmental age is carried out to further elucidate the developmental structural argument.

6.3.4 Disadvantages of transdiagnostic investigation

While there are many merits in answering the call-out for more transdiagnostic research efforts, there are limitations and critiques of the approach that warrant attention. And as examining dysfunction across the diagnostic spectrum was born out of the RDoC project, it is appropriate to consider the limitations in the context of the wider RDoC perspective. The RDoC assumption pertaining to mental illness as illnesses of the brain could be interpreted as reductionist (Franklin et al., 2015; Sanislow et al., 2010). Certainly, it can be argued that there are limitations to how far biological phenomena can explain psychological phenomena (Miller, 2010). And as many diagnostic classifications are informed by genetic anomalies (including diagnoses incorporated in our sample), one has to question how far our assessment of the EF-behaviour-context relationship should be treated as transdiagnostic. Indeed, there may be other important diagnosis-specific variables which might provide a discernible explanation for the presentations displayed by the children and their interactions with the environment. Further, it is possible accumulating differential diagnosis-specific variables in a sample in this way, may have diluted or even eradicated their impact on the findings. Previous work on behavioural phenotypes has investigated the association of ASD-related phenomenology and genetically-determined syndromes (Moss & Howlin, 2009). The findings highlight that not only is there a high prevalence of ASD symptomology in different syndrome groups, there are also subtle differences in the presentation of such symptoms between groups. Furthermore, it was suggested the severity of intellectual disability impacts the development and expression of ASD-like characteristics in the sample. Therefore, it is possible there are confounding behavioural phenotypes within and across our diagnostic groups that could provide a further explanation for the contextually-defined classification identified in this work.

6.4 Merits of the research

6.4.1 Holistic perspective

While this work adopted a focused view in examining the role of EF in behaviour, there are a number of features of the research that are holistic. The trajectory of examining the neural activation of a construct, right through to the effect of environmental factors on the expression of that construct encapsulates this. Indeed, the consideration of EF at the level of neural activity, as well as the effect of non-executive noise at that neural level offers a solid basis for examining EF at higher levels, i.e. its impact on behaviour. While there are limitations associated with every point on said investigative trajectory, as well as the connections between the studies conducted, efforts to carry out a comprehensive assessment of a putative construct of interest in this way is a worthy endeavour.

Another way this research allowed a comprehensive investigation is in the assessment of multiple executive processes. There are many studies presented in the literature that focus on the neural correlates of one executive process, or the impact of one executive process on behaviour. Therefore, examining the three main executive processes in a typical child sample at a neural level and again, in a clinical sample while also investigating behaviour, ER and context, affords a thorough assessment of the relationships at play. Furthermore, the continuation of measuring inhibition, switching and updating in the IN CONTROL study augments the findings of the fMRI meta-analysis, and provides more support for the integrative structure of EF in children.

6.4.2 Multiple units of analysis

There are a number of merits associated with the methodology used in this work, both from scientific and clinical perspectives. While there are limitations associated with such an approach, systematic meta-analytic investigations of large amounts of fMRI data provides a rich and robust perspective on the neural environment of EF. Further, additional analyses aiming to extract non-executive variance embedded in EF task data, so as to inform on better assessment of EF performance, adds to the strengths of the research.

The interview approach described in chapter 4 provided detailed contextual information from parents, which informed on contextual group classification.

Gaining qualitative data in this form explored real life everyday impairments, which were at the core of the research. The novel approach employed went beyond the confines of acquiring knowledge on behaviour problems in wider contexts, such as school, home, relationships, as is typical in the assessment of behavioural difficulties. Furthermore, the tool utilised in this work did not restrict parents in only considering previously selected contextual events, but allowed them to introduce additional examples that were more relevant for their child. It is this connection with everyday life that truly advances our understanding of mechanisms involved in atypical presentations, such as behavioural difficulties. The role of the parents in shaping the investigation is a significant strength of this work, as it promotes integration of the research-to-practice initiative right from the very start of investigation.

As well as utilising well validated psychometric measures, the use of a comprehensive battery of EF tests allowed a detailed picture of executive processing – using an online medium that children are familiar with, and which instilled interest during administration. Not only was the battery informed by the fMRI meta-analysis studies, but the inclusion of a storyline involving a central character- Bizz, an alien who participants help to get back to this home planet by completing tasks, acted as a great motivator for completion. There is a growing evidence that gamification of cognitive assessments enhances participant engagement, which can be a particular benefit to EF tests, given their largely repetitive and effortful nature (Lumsden, Edwards, Lawrence, Coyle, & Munafò, 2016). Therefore, it was hoped the admission of a storyline and game-like features in our battery promoted task enjoyment and interest.

6.4.3 Development of new tools

Efforts to develop this new EF tool, was in part, aided by work presented in the first part of this thesis. And once created, was integral to the assessments carried in the second part of the thesis. It is essential to contribute to developing new measures for use by researchers and clinicians, to ensure progressive and up-to-date research outputs. It is hoped these tools will help stimulate new EF developmental research and in particular, contribute to the pursuit of remedying the specific constraints in EF assessment.

Further, the development of the context measure, detailed in chapter 3 afforded precise and detailed accounts of emotionally salient situations which elicit clinically relevant behaviours in children, as well as the profile of behaviour shown and the clinical impact of the behaviour. This measure was intended to obtain very specific information relevant to the aims of the research project and thus, may or may not be a transferable tool to be used in other research endeavours. However, it is possible the measure may act as a template for future investigations, perhaps with differing contextual requirements but similar methodological objectives.

6.4.4 Contribution to the RDoC

The findings of this work assist in the advancement of the RDoC initiative. Assessing EF as a marker for atypical behaviour presentations in children in this way furthers our understanding of transdiagnostic impairment. It is hoped the consideration of context, as we have examined it, stimulates further research into how contextual impairments can influence transdiagnostic mechanisms, such as EF.

Certainly, the omission of the consideration of environmental factors on such markers, particularly in the context of development, has been presented as a critique of the RDoC approach (Franklin et al., 2015). Therefore, the emphasis on the dynamic nature of contextual interference on executive processing, as demonstrated in this research, enhances the transdiagnostic perspective and marries it with the established outlook of developmental research.

Furthermore, the inclusion of ER as a contributory factor in this dynamic interplay complements the RDoC position, particularly in light of developmental progression. Franklin et al. (2015) postulates that the constructionist view of emotion, as adopted in this work, acts as a natural accompaniment to the aims of the RDoC. Not only this, a constructionist emotion-focused approach to RDoC may alleviate some of the previously discussed limitations associated with the position. Therefore, assessing ER as a transdiagnostic mechanism and examining its interaction with other markers, such as EF, furthers the application of the transdiagnostic approach in child psychopathology research.

6.5 Implications and Future Directions

6.5.1 Structure of EF deficits

As the meta-analysis in chapter 2 highlights, the structure of EF consists of both overarching and dissociative processes. Further, no updating and switching-specific processes were evident in the child-only sample (aged 6-12 years) at a neural level. Therefore, additional research into whether such deficits are indicative of process-specific impairments or attributable to a common EF impairment must be carried out. As the current literature suggests there is a paucity of such clarifications (Bloemen et al., 2018). Certainly, the evidence from the IN CONTROL study, as discussed in chapter 5, indicates that although the children in the SC group performed better in all the EF domains (including common EF), their updating ability was poorer than that of the children in the non-SC group, suggesting an updating-specific impairment. Therefore, future research examining EF deficits in children of this age should endeavour to assess EF at a common and specific level. Investigating both components in the assessment of EF is integral to the development of effective interventions for this age group. Moreover, results from the meta-analysis supported the view that in childhood, a commonality between the 3 EF processes is evident and that updating and switching separate from common EF with increasing age. Indeed, evidence points towards process-specific features in adolescence. As previously discussed in section 6.2.1, future work must aim to uncover how and specifically, when, these processes discriminate during development. As gaining this information may better inform on age-appropriate intervention, i.e. advising which specific executive processes to target and when.

6.5.2 Focused investigation of updating and self-focused maladaptive ER

While a holistic approach assessing inhibition, switching and updating was a particular strength of this research, given the explorative nature of the work, the relationship between updating and self-focused ER in the light of the contexts explored, must be examined in more detail. The findings that updating interacts with self-focused maladaptive ER in such a way as to act as a cognitive liability for contextual impairment in some, but also act as a defence against such impairment in others, warrants further investigation. Our theoretical stance postulated that emotionally salient contextual information can interfere with and ultimately disrupt EF processing.

A focused examination of self-focused maladaptive ER strategies and information pertaining to the view of the self-concept could provide a basis for future work. It is possible such an investigation could detail a specific pathway to contextual impairment which has the potential to exert influence on prescribed clinical interventions. In addition, another factor that may have a substantial impact on deficits in the contexts explored here, is that of parenting style, and in particular, parenting responses to the putative contextual demands. Such parenting information was retrieved during the study, but not inputted into the regression models. Thus, examination of this data in light of the current findings may provide an additional dimension to the results reported.

6.5.3 Clinical Interventions

Efforts to develop interventions to improve EF are a hallmark of the literature, with decidedly mixed results (Diamond & Ling, 2016). There are arguably more numerous efforts to intervene by improving emotion regulatory abilities. And further, interventions combining efforts to improve EF and emotional dysregulation have been conducted in adolescent samples, with the use of mindfulness-based programmes (Kiani, Hadianfard, & Mitchell, 2017). Diamond and Ling (2016) propose the most fruitful way to improve EF is to not only directly target EF, but to aim to improve aberrant emotional, social and behavioural functioning. In addition, as previously discussed in chapter 4, established intervention work directed at identifying contextual triggers and consequences has been highly successful in the regulation of behaviour, which has, in particular, been adopted for use in the ASD population (Hanley et al., 2003). However, as the evidence of this thesis suggests there is a dynamic interplay between EF, ER and putative contextual demands in children with and without diagnoses, multi-faceted treatments are needed. It is possible that interventions which target these processes and demands at the various levels required would prove beneficial to reducing behavioural and emotional dysfunction in this population. However, of note, the specificity of the contextual demands identified in this work (i.e. the deleterious effect the environmental stimulus has on the self-concept), would warrant a prescribed treatment approach. Accordingly, it could be argued a multi-level, yet, focused intervention would be required.

This comprehensive but flexible approach is indicative of the objectives of transdiagnostic interventions. These treatments advocate flexibility in the development of such approaches, in order to cater for the wide array of clinical issues that present in many diagnoses, particularly in childhood (Chu, 2012). Transdiagnostic approaches view clinical problems as a collection of dimensional dysfunctions and thus aim to target a number of dimensions during intervention. Complementary to our findings, such interventions consider problems not only at the intra-person level (cognitive, emotional, behavioural) but at a systemic level (environmental contexts). Racer and Dishion (2012) provide a comprehensive commentary on executive attention as a transdiagnostic component across internalising and externalising disorders in youth and suggest executive attention – defined as a subset of EF, may act as a risk factor in maintaining symptoms associated with these disorders. It is important to note that many treatment models require children to use executive skills to implement the teachings of the programmes and thus, it could be argued that children with deficits in this area would be at a disadvantage in terms of clinical improvement. The authors suggest that executive attention training if used alongside traditional therapeutic treatments would enhance clinical outcomes, so that children would be better equipped to over-ride negative thinking patterns for instance, and to generalise their in-session learning to their everyday life.

Another transdiagnostic approach complementing multi-level integration combines a group-based CBT intervention for co-occurring anxiety and depression in youth, with prescribed concurrent parenting classes (Ehrenreich-May & Bilek, 2012). This inclusion of parenting interventions is paramount to the consideration of context in therapeutic models. While context has long been considered by clinicians in the assessment of child psychopathology- particularly in the case of behavioural difficulties, it has not been incorporated into measurement tools. Further, historically, behavioural variability across contexts has been viewed by clinicians as a reason against diagnosis, and thus has been perceived as not clinically meaningful (Dirks et al., 2012). However, as new transdiagnostic perspectives have gained increased support, the admission of the impact of contextual factors on symptomatology is being perceived as increasingly more important for effective clinical intervention.

Another factor to consider in the treatment of “transdiagnostic” groups is the inclusion of children without traditional developmental diagnoses. As it must be highlighted that while there was no significant difference in internalising and externalising behaviours between the diagnostic groups in our study- which of course supports the transdiagnostic perspective. A finding that is worthy of note is that children without a diagnosis at time of participation expressed significantly more internalising behaviour problems than children with a diagnosis. Anecdotally, it was reported that such children were not receiving support from psychological services because of their lack of developmental diagnosis, yet psychological intervention is evidently warranted. This finding poses concerns for service provision and questions the allocation of such resources, as it appears children with a distinct psychological need are being missed. Therefore, not only could this research promote transdiagnostic intervention work with children across the diagnostic spectrum, but it could also aid the development of interventions that are aimed toward *any* child who presents with such clinically relevant difficulties.

6.6 Concluding Remarks

The work of this thesis furthers our understanding of the structure of EF in development, the influence of non-executive task demands on neural activation, the clinical impact of emotionally salient contexts on the expression of behavioural difficulties and importantly, the role of EF and ER in predicting specific contextual impairment. The research conducted draws from fMRI neuroscientific meta-analytic methodology, parental interviews, psychometric measurements and the EF battery approach. Furthermore, the work contributes to the development of contextualised measurement tools, while advocating a transdiagnostic perspective. Evidence indicates an EF neural structure representing common and process-specific components in children. Further, examination of non-executive task demands revealed the influence of specific stimuli modalities and test-types on executive activation. The development of a contextual measurement tool allowed the identification of functional groupings which elicited clinically relevant behavioural difficulties. Findings revealed groupings were differentiated by the impact the context had on the child's self-concept. Investigations into the role of EF and ER in contextual impairment identified specific profiles of deficit in these processes, which predicted specific deficits in contexts that threatened the self-concept and contexts that do not threaten the self-concept. Future research efforts to shed light on such profiles of impairment are needed, to further elucidate the context-EF/ER-behaviour relationship identified in this work. It is hoped such work will inform on the development of new assessment tools which consider the role of executive and contextual demands on behavioural difficulties in children. Furthermore, prospective new transdiagnostic interventions which complement this progress by positioning executive and contextual impairment at the heart of their approach, will greatly help to ameliorate emotional and behavioural dysfunction in children.

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Appendix A. Detailed cluster demographics for first-level analyses for Common Executive, Inhibition, Updating & Switching in the child/adolescent group

	Cluster #	Volume (mm^3)	Weighted Centre (x,y,z)			Region
Common Executive	1	8648	1.01	15.75	46.18	Left Medial Frontal Gyrus (BA 32 & 6)
	2	5312	29.77	-55.81	48.58	Right Inferior Parietal Lobule (BA 40) Right Superior Parietal Lobule (BA 7) Right Precuneus (BA 7)
	3	4880	39.49	21.29	-4.9	Right Insula Right Claustrum
	4	2376	-30.83	-49.47	48.18	Left Inferior Parietal Lobule (BA 40) Left Superior Parietal Lobule (BA 7) Left Precuneus (BA 7)
	5	1760	-32.59	20.39	1.76	Left Insula (BA 13)
	6	1496	36.12	42.31	31.02	Right Middle Frontal Gyrus (BA 9)
	7	1368	-46.65	6.2	31.79	Left Precentral Gyrus (BA 6) Left Middle Frontal Gyrus (BA 9)
	8	1176	-22.26	6.12	53.7	Left Frontal Sub-Gyral Matter (BA 6)
	9	904	47.19	5.81	31.56	Right Precentral Gyrus (BA 6)
	10	840	43.89	-61.17	-8.59	Right Fusiform Gyrus (BA 37 & 19)
	11	664	30.34	9.71	56.72	Right Frontal Sub-Gyral Matter (BA 6)
	12	584	-23.23	-65.86	39.7	Left Precuneus (BA 7)
	13	520	-43.79	31.16	32.59	Left Middle Frontal Gyrus (BA 9)
	14	448	36.23	-57.1	-26.51	Right Culmen
	15	448	26.91	-0.14	48.53	Right Middle Frontal Gyrus (BA 6)
	16	440	-7.95	-67.3	60.06	Left Superior Parietal Lobule (BA 7) Left Precuneus (BA 7)
	17	432	10.78	17.18	-2.69	Head of the Right Caudate nucleus
	18	384	47.24	-20.98	44.7	Right Postcentral Gyrus (BA 2)
	19	360	-40.63	-61.03	-26.43	Left Culmen Left Posterior Lobe of Cerebellum
	20	360	-11.79	1.57	14.52	Body of the Left Caudate nucleus

	21	304	55.16	-43.06	51.89	Right Inferior Parietal Lobule (BA 40)
	22	248	23.74	-68.91	33.17	Right Precuneus (BA 7)
	23	200	-53.11	-4.18	44.06	Left Precentral Gyrus (BA 4)
	24	184	4.49	-7.21	43.72	Right Cingulate Gyrus (BA 24)
	25	144	55.11	-42.99	31.98	Right Inferior Parietal Lobule (BA 40)
	26	120	5.47	-17.07	-9.21	Red Nucleus, Right Midbrain
	27	120	-39.86	-79.71	-3.06	Left Inferior Occipital Gyrus (BA 19)
	28	112	-27.59	-78.14	23.28	Left Middle Occipital Gyrus (BA 19)
	29	104	-44.95	26.77	1.99	Left Inferior Frontal Gyrus (BA 13)
Inhibition	1	6520	1.92	13.99	46.49	Right Cingulate Gyrus (BA 32) Left Medial Frontal Gyrus (BA 32 & 6) Right Medial Frontal Gyrus (BA 6) Right Superior Frontal Gyrus (BA 6)
	2	4432	43.01	20.29	-5.22	Right Extra-Nuclear. (BA 47) Right Insula (BA 13)
	3	2560	27.09	-58.59	51.05	Right Precuneus (BA 7) Right Inferior Parietal Lobule (BA 40) Right Superior Parietal Lobule (BA 7)
	4	1776	-35.74	20.86	2.41	Left Insula (BA 13) Left Inferior Frontal Gyrus (BA 13) Left Inferior Frontal Gyrus (BA 45)
	5	952	10.97	17.27	-2.71	Head of the Right Caudate nucleus
	6	680	35.38	42.92	33.16	Right Middle Frontal Gyrus (BA 9)
	7	640	43.47	-58.79	-9.03	Right Fusiform Gyrus (BA 37)
	8	456	55.38	-43.71	32.24	Right Inferior Parietal Lobule (BA 40)
	9	408	-39.28	-79.32	-3.17	Left Inferior Occipital Gyrus (BA 19)
	10	400	-35.7	41.04	24.13	Left Superior Frontal Gyrus (BA 9)
	11	376	59.85	-40.89	13.09	Right Superior Temporal Gyrus (BA 22)
	12	336	-10.28	5.54	12.46	Body of the Left Caudate nucleus
	13	336	26.75	0	47.24	Right Middle Frontal Gyrus (BA 6)
	14	320	-24.37	-55.79	59.83	Left Precuneus (BA 7)

	15	272	22.44	-70.53	34	Right Precuneus (BA 31)
	16	256	-50.54	8.07	-3.84	Left Superior Temporal Gyrus (BA 22)
	17	232	50.01	5.99	30.01	Right Inferior Frontal Gyrus (BA 6)
	18	216	34.02	-57.69	-24.33	Right Culmen
	19	168	11.74	1.55	68.12	Right Superior Frontal Gyrus (BA 6)
	20	160	-29.09	-51.5	49.08	Left Precuneus (BA 7) Left Superior Parietal Lobule (BA 7)
Updating	1	3856	-0.36	17.41	46.32	Left Medial Frontal Gyrus (BA 6) Left Cingulate Gyrus (BA 24) Left Superior Frontal Gyrus (BA 6)
	2	1640	49.33	15.76	21.81	Right Inferior Frontal Gyrus (BA 44 & 9) Right Precentral Gyrus (BA 9) Right Middle Frontal Gyrus (BA 9)
	3	1504	40.12	-45.88	44.96	Right Inferior Parietal Lobule (BA 40)
	4	1232	-40.7	-66.06	-30.16	Left Posterior Lobe of Cerebellum Left Posterior Lobe of Cerebellum
	5	1192	35.24	22.12	-2.56	Right Insula
	6	1176	30.29	9.54	56.77	Right Frontal Sub-Gyral Matter (BA 6)
	7	1040	-24.69	7.46	52.41	Left Frontal Sub-Gyral Matter (BA 6)
	8	1016	-33.45	-45.37	42.4	Left Inferior Parietal Lobule (BA 40)
	9	880	31.48	-62.67	37.92	Right Precuneus (BA 7)
	10	680	-32.05	19.94	0.6	Left Claustrum
	11	656	-8.54	-65.5	61.93	Left Superior Parietal Lobule (BA 7)
	12	520	-40.99	1.94	35.51	Left Precentral Gyrus (BA 6) Left Inferior Frontal Gyrus (BA 6)
	13	488	-20.99	-63.99	41.96	Left Precuneus (BA 7)
	14	384	38.68	-60.09	-34.57	Right Anterior Lobe of Cerebellum Right Posterior Lobe of Cerebellum
	15	360	53.85	-42.37	52.63	Right Inferior Parietal Lobule (BA 40)
	16	320	37.46	35.67	26.99	Right Middle Frontal Gyrus (BA 9)
	17	288	-31.71	-51	56.59	Left Superior Parietal Lobule (BA 7)
	18	280	-43.21	-5.9	55.21	Left Precentral Gyrus (BA 4)

	19	264	16.82	-68.28	46.47	Right Precuneus (BA 7)
	20	224	-14.07	-2.08	17.21	Body of the Left Caudate nucleus
	21	192	37.35	-2.5	52.44	Right Precentral Gyrus (BA 6)
	22	152	-38.55	25.92	26.42	Left Middle Frontal Gyrus (BA 9)
	23	128	-54.39	24.37	34.38	Left Middle Frontal Gyrus (BA 9)
	24	112	17.58	-74.59	49.71	Right Precuneus (BA 7)
	25	104	52.17	0.94	43.81	Right Precentral Gyrus (BA 6)
Switching	1	488	48.52	-21.47	44	Right Postcentral Gyrus (BA 2)
	2	288	4.23	-8.34	44.05	Right Cingulate Gyrus (BA 24)
	3	272	-6.8	-72.46	4.07	Left Lingual Gyrus (BA 18)
	4	168	-46.69	3.31	29.07	Left Precentral Gyrus (BA 6)

BA, Brodmann area.

Appendix B. Detailed cluster demographics for first-level analyses for Common Executive and Inhibition in the child group

	Cluster #	Volume (mm^3)	Weighted Centre (x,y,z)			Region
Common Executive	1	7352	0.38	15.48	46.66	Left Medial Frontal Gyrus (BA 32 & 6)
	2	2024	39.14	-46.52	44.61	Right Inferior Parietal Lobule (BA 40)
	3	1704	34.63	21.08	2.19	Right Claustrum Right Insula
	4	1504	22.32	-63.49	46.28	Right Precuneus (BA 7)
	5	1120	-19.66	4.08	55.94	Left Frontal Sub-Gyral Matter (BA 6)
	6	1000	28.48	-0.57	48.92	Right Middle Frontal Gyrus (BA 6) Right Precentral Gyrus (BA 6)
	7	840	35.99	42.97	32.26	Right Middle Frontal Gyrus (BA 9)
	8	696	53.5	10.48	16.61	Right Inferior Frontal Gyrus (BA 44 & 9)
	9	680	-31.78	21.67	2.75	Left Insula (BA 13)
	10	456	-10.39	4.71	12.5	Body of the Left Caudate nucleus
	11	400	16.53	-77.48	50.22	Right Precuneus (BA 19)
	12	320	49.83	17.55	-11.37	Right Inferior Frontal Gyrus (BA 47)
	13	296	-40.08	1.59	36.91	Left Precentral Gyrus (BA 6)
	14	264	54.8	-41.78	31.05	Right Inferior Parietal Lobule (BA 40)
	15	256	54.17	-42.28	52.3	Right Inferior Parietal Lobule (BA 40)
	16	256	-43.53	-6	54.58	Left Precentral Gyrus (BA 4)
	17	248	43.61	-58.2	-10.06	Right Fusiform Gyrus (BA 37)
	18	240	42.2	-0.47	37.45	Right Precentral Gyrus (BA 6)
	19	232	24.15	45.28	-11.59	Right Medial Frontal Gyrus (BA 10)
	20	224	-22.66	19.07	54.58	Left Superior Frontal Gyrus (BA 6)
	21	216	-20.53	-64.49	39.94	Left Precuneus (BA 7)
	22	208	44.37	22.46	37.25	Right Middle Frontal Gyrus (BA 8) Right Precentral Gyrus (BA 9)
	23	208	-6.63	-71.86	55.37	Left Precuneus (BA 7)
	24	192	-34.34	-51.51	45.43	Left Inferior Parietal Lobule (BA 40)
	25	184	15.92	18.71	-2.88	Head of the Right Caudate nucleus
	26	160	29.89	10.01	57.91	Right Frontal Sub-Gyral Matter (BA 6)

	27	152	-15.6	-98.73	6.72	Left Cuneus (BA 17)
	28	144	-0.44	3.54	22.22	Left Cingulate Gyrus (BA 24)
	29	120	28.41	59.46	10.94	Right Middle Frontal Gyrus (BA 10)
	30	120	24.28	-62.01	63.32	Right Superior Parietal Lobule (BA 7)
Inhibition	1	4288	0.88	15.86	46.01	Left Medial Frontal Gyrus (BA 32) Left Superior Frontal Gyrus (BA 6) Right Medial Frontal Gyrus (BA 8 & 6) Right Superior Frontal Gyrus (BA 6)
	2	904	35.45	43.43	33.05	Right Middle Frontal Gyrus (BA 9)
	3	584	-10.03	5.2	12.61	Body of the Left Caudate nucleus
	4	472	15.4	18.59	-2.8	Head of the Right Caudate nucleus
	5	440	26.86	-0.21	47.1	Right Middle Frontal Gyrus (BA 6)
	6	408	34.13	20.97	7.16	Right Insula (BA 13)
	7	400	55.07	-41.85	31.08	Right Inferior Parietal Lobule (BA 40)
	8	384	43.34	-58.48	-10.12	Right Fusiform Gyrus (BA 37)
	9	384	34.71	-50.5	45.13	Right Superior Parietal Lobule (BA 7)
	10	312	26.91	-63.06	47.23	Right Superior Parietal Lobule (BA 7)
	11	280	51.68	16.78	-10.6	Right Inferior Frontal Gyrus (BA 47)
	12	256	-22.11	19.7	55.47	Left Superior Frontal Gyrus (BA 6)
	13	200	-45.92	7.43	-1.61	Left Insula (BA 13)
	14	152	-36.46	-77.23	-5.13	Left Inferior Occipital Gyrus (BA 19)
	15	128	-16.14	2.87	60.49	Left Middle Frontal Gyrus (BA 6)
	16	120	-11.34	16.54	-1.34	Head of the Left Caudate nucleus
	17	120	51.19	15.32	2.27	Right Precentral Gyrus (BA 44)
	18	112	39.86	-40.41	44	Right Inferior Parietal Lobule (BA 40)

BA, Brodmann area.

Appendix C. Second-level Conjunction and Contrast Analyses for Common Executive (update, switch) and Inhibition in the child/adolescent group

	Cluster #	Volume (mm^3)	Weighted Center (x,y,z)			Region
Conjunction	1	2776	0.66	16.22	45.66	Left Medial Frontal Gyrus (BA 32) Left Superior Frontal Gyrus (BA 6)
	2	432	-32.07	20.87	1.35	Left Insula (BA 13)
	3	320	37.35	22.66	-5.77	Right Insula
	4	96	38.99	-49.98	46.99	Right Inferior Parietal Lobule (BA 40)
	5	56	32.3	20.3	4.54	Right Claustrum
	6	48	29.31	-61.68	46.67	Right Superior Parietal Lobule (BA 7)
	7	8	46	6	30	Right Precentral Gyrus (BA 6)
	8	8	26	-62	44	Right Precuneus (BA 7)
	9	8	-32	-52	54	Left Superior Parietal Lobule (BA 7)
	10	8	-32	-54	56	Left Superior Parietal Lobule (BA 7)
Difference	No clusters found					

BA, Brodmann area.

Appendix D. Second-level Conjunction and Contrast Analyses for Common Executive (update, switch) and Inhibition in the child group

	Cluster #	Volume (mm^3)	Weighted Center (x,y,z)			Region
Conjunction	1	2160	0.2	16.1	45.8	Left Medial Frontal Gyrus (BA 32)
						Left Medial Frontal Gyrus (BA 6)
						Right Cingulate Gyrus (BA 32)
						Right Medial Frontal Gyrus (BA 6)
	2	96	32.3	20.5	5.3	Right Claustrum
	3	48	40.7	-41	43.4	Right Inferior Parietal Lobule (BA 40)
	4	48	27	-62.7	44.7	Right Precuneus (BA 7)
	5	40	38	-49.2	45.6	Right Inferior Parietal Lobule (BA 40)
Difference	No clusters found					

BA, Brodmann area.

Appendix E. Second-level Conjunction and Contrast Analyses for Common Executive (inhibit, switch) and Updating in the child/adolescent group

	Cluster #	Volume (mm^3)	Weighted Centre (x,y,z)			Region
Conjunction	1	2576	0.72	16.18	46.52	Left Medial Frontal Gyrus (BA 6 & 32) Left Superior Frontal Gyrus (BA 6)
	2	440	-32.01	21.03	1.57	Left Insula (BA 13)
	3	280	37.46	23.09	-6.05	Right Insula
	4	120	-30.07	-47.71	42.8	No Grey Matter found
	5	120	38.34	-49.99	46.69	Right Inferior Parietal Lobule (BA 40)
	6	72	28.02	-61.99	46.65	Right Superior Parietal Lobule (BA 7)
	7	56	32.56	20.32	4.55	Right Claustrum
	8	40	-45.2	4.81	32	Left Inferior Frontal Gyrus (BA 6) Left Precentral Gyrus (BA 6)
Difference	1	1136	30.27	9.18	56.7	Right Frontal Sub-Gyral Matter (BA 6) Right Middle Frontal Gyrus (BA 6)
	2	760	45.34	19.75	23.99	Right Middle Frontal Gyrus (BA 9) Right Precentral Gyrus (BA 9)
	3	672	-40.93	-67.21	-31.57	Left Posterior Lobe of Cerebellum Left Posterior Lobe of Cerebellum
	4	144	38.79	-63.16	-39.27	Right Posterior Lobe of Cerebellum

BA, Brodmann area.

Appendix F. Second-level Conjunction and Contrast Analyses for Common Executive (inhibit, switch) and Updating in the child group

	Cluster #	Volume (mm^3)	Weighted Center (x,y,z)			Region
Conjunction	1	2208	0.3	16.2	45.8	Left Medial Frontal Gyrus (BA 32) Left Medial Frontal Gyrus (BA 6) Right Cingulate Gyrus (BA 32) Right Medial Frontal Gyrus (BA 6)
	2	104	32.6	20.6	5.2	Right Claustrum
	3	56	40.6	-41.1	43.7	Right Inferior Parietal Lobule (BA 40)
	4	48	27	-62.7	44.7	Right Precuneus (BA 7)
	5	40	38	-49.2	45.6	Right Inferior Parietal Lobule (BA 40)
	6	8	36	-48	42	Right Inferior Parietal Lobule (BA 40)
Difference	No clusters found					

BA, Brodmann area.

[Image 3]

Appendix G. Second-level Conjunction and Contrast Analyses for Common Executive (inhibit, update) and Switching

	Cluster #	Volume (mm^3)	Weighted Centre (x,y,z)			Region
Conjunction	1	88	-45.28	3.59	30.14	Left Precentral Gyrus (BA 6)
Difference	1	192	-5.6	-72.66	3.18	Left Lingual Gyrus (BA 18)

BA, Brodmann area.

Appendix H. Contrast clusters from the Control Analyses for Common Executive and Updating

Cluster #	Volume (mm^3)	Weighted Centre (x,y,z)			Region
1	216	52.37	-42.44	55.78	Right Inferior Parietal Lobule (BA 40)
2	304	37.81	-1.79	53.17	Right Middle Frontal Gyrus (BA 6)
3	104	-30.88	-69.72	-25.72	Left Posterior Lobe of Cerebellum

BA, Brodmann area.

Appendix I. Second-level Conjunction and Contrast Analyses for Common Executive (inclusive) and Inhibition

	Cluster #	Volume (mm^3)	Weighted Centre (x,y,z)			Region
Conjunction	1	5976	1.91	14.43	46.17	Right Cingulate Gyrus (BA 32) Left Medial Frontal Gyrus (BA 32 & 6) Right Medial Frontal Gyrus (BA 6) Right Superior Frontal Gyrus (BA 6)
	2	3464	42	20.82	-6.04	Right Extra-Nuclear (BA 47) Right Insula (BA 13)
	3	1616	23.27	-61.55	52.44	Right Precuneus (BA 7) Right Superior Parietal Lobule (BA 7)
	4	1232	-32.96	20.74	2.61	Left Insula (BA 13)
	5	744	35.75	-52.09	46.77	Right Inferior Parietal Lobule (BA 40)
	6	544	35.77	42.99	32.97	Right Middle Frontal Gyrus (BA 9)
	7	512	43.61	-59.02	-8.75	Right Fusiform Gyrus (BA 37)
	8	432	10.78	17.19	-2.69	Head of the Right Caudate nucleus
	9	288	26.76	-0.14	47.56	Right Middle Frontal Gyrus (BA 6)
	10	232	-24.83	-55.66	59.6	Left Precuneus (BA 7)
	11	224	49.95	6.05	30.07	Right Inferior Frontal Gyrus (BA 6)
	12	176	34.34	-57.48	-24.55	Right Culmen
	13	168	23.17	-69.83	33.83	Right Precuneus (BA 31)
	14	160	-10.13	4.67	12.79	Body of the Left Caudate nucleus
	15	160	-29.09	-51.5	49.08	Left Precuneus (BA 7) Left Superior Parietal Lobule (BA 7)
	16	144	55.11	-43	31.97	Right Inferior Parietal Lobule (BA 40)
	17	120	-39.86	-79.71	-3.06	Left Inferior Occipital Gyrus (BA 19)
	18	104	-44.94	26.76	1.97	Left Inferior Frontal Gyrus (BA 13)
Difference	No Clusters found					

BA, Brodmann area.

Appendix J. Second-level Conjunction and Contrast Analyses for Common Executive (inclusive) and Updating

	Cluster #	Volume (mm^3)	Weighted Center (x,y,z)			Region
Conjunction	1	3840	-0.34	17.42	46.31	Left Medial Frontal Gyrus (BA 6) Left Cingulate Gyrus (BA 24) Left Superior Frontal Gyrus (BA 6)
	2	1272	39.96	-45.89	44.99	Right Inferior Parietal Lobule (BA 40) Right Inferior Parietal Lobule (BA 40)
	3	1192	35.24	22.12	-2.56	Right Insula
	4	808	-33.08	-45.73	42.43	Left Inferior Parietal Lobule (BA 40)
	5	808	-24.17	7.34	52.62	Left Frontal Sub-Gyral (BA 6)
	6	680	-32.05	19.94	0.6	Left Claustrum
	7	664	30.35	9.68	56.72	Right Frontal Sub-Gyral Matter (BA 6)
	8	360	30.24	-61.8	45.49	Right Precuneus (BA 7)
	9	320	-8.27	-66.06	61.66	Left Superior Parietal Lobule (BA 7)
	10	296	-21.43	-64.71	40.62	Left Precuneus (BA 7)
	11	288	-31.71	-51	56.59	Left Superior Parietal Lobule (BA 7)
	12	240	37.6	35.8	27.58	Right Middle Frontal Gyrus (BA 9)
	13	232	54.57	-42.49	52.19	Right Inferior Parietal Lobule (BA 40)
	14	216	-42.74	3.12	33.76	Left Precentral Gyrus (BA 6) Left Inferior Frontal Gyrus (BA 6)
	15	160	-42.47	-65.46	-27.58	Left Posterior Lobe of Cerebellum
	16	120	-14	-1.53	16.84	Left Caudate
	17	112	15.97	-66.32	47.97	Right Precuneus (BA 7)
	18	104	38.34	-57.22	-29.75	Right Anterior Lobe of Cerebellum
	19	32	-38.01	28	27.48	Left Middle Frontal Gyrus (BA 9)
	20	8	-40	-62	-24	Left Posterior Lobe of Cerebellum
Difference	No clusters found					

BA, Brodmann area.

Appendix K. Second-level Conjunction and Contrast Analyses for Common Executive (inclusive) and Switching

	Cluster #	Volume (mm^3)	Weighted Center (x,y,z)			Region
Conjunction	1	320	47.9	-21.33	44.23	Right Postcentral Gyrus (BA 2)
	2	160	4.45	-7.65	43.89	Right Cingulate Gyrus (BA 24)
	3	152	-46.17	3.24	29.47	Left Precentral Gyrus (BA 6)
Difference	No clusters found					

BA, Brodmann area.

Appendix L. The Context Measure

Participant ID:

We would like you to think about any difficulties you child shows with their behaviour in the following scenarios:

1. After feeling that he/she is being criticised e.g. when other make negative comments about him/her, or when others tease or ridicule him/her.

2. As a result of a disappointment, e.g. when they receive a less preferred outcome than they were hoping for, i.e. when their sports team loses, or when they cannot have something they want or cannot continue with a preferred activity.

3. As a result of a perceived failure, in other words when they can't achieve a goal, make errors in their work or can't complete a task to the best of their ability.

4. After feeling that he/she is being treated unfairly, e.g when something is being shared out and he/she receives less than someone else.

Please tell us which one of the below scenarios has the biggest negative impact on your child's life.

- ◯ Being criticised
- ◯ A disappointment

○ A perceived failure

○ Being treated unfairly

○ Another situation (please describe)

<u>Open-ended question:</u> Please describe a situation in which your child has shown difficulties with their behaviour after [insert relevant context of interest i.e. feeling criticised/a perceived failure/a disappointment/being treated unfairly].

When this situation occurs, does he/she show behaviour that is: (if applicable, please tick)

☐ Aggressive (e.g. punching, pushing, kicking, pulling hair, grabbing other's clothing etc.)

☐ Destructive (e.g. throwing or stamping on objects which can result in damage to the object)

☐ Fearful (e.g. fears going to school; fears certain animals, situations or places; fears he/she might think or do something bad)

☐ Insecure (e.g. clingy; feels or complains no one loves him/her; feels worthless or inferior; self-conscious or easily embarrassed)

☐ Irritable (e.g. stubborn; sullen; sulks a lot)

☐ Nervous (e.g. highly strung; tense; shows nervous movements or twitching)

☐ Non-compliant (e.g. failing to follow or doing the opposite of an instruction, directive or request)

☐ Self-injury (e.g. an action towards the self (e.g hitting or biting) that has the potential to cause harm and can result in tissue damage)

☐ Somatic complaints (e.g. complains of physical problems without known medical cause)

☐ Temper tantrums (e.g. a sudden/explosive episode of behaviours that may include arguing, shouting, screaming, facial flushing, stamping, angry facial expression, 'storming off,' destruction and/ or aggression)

☐ Thought problems (e.g. worries a lot; can't get his/her mind off certain thoughts)

☐ Unhappy (e.g. cries a lot; complains of loneliness)

☐ Withdrawn (e.g. doesn't get involved with others; refuses to talk; keeps things to self)

☐ Other (please describe)

____

- [ ] None of the above

Overall, how would you rate the difficulties your child has in this situation?

- ○ No difficulties
- ○ Yes - minor difficulties
- ○ Yes - definite difficulties
- ○ Yes - severe difficulties

If you answered 'Yes,' please answer the following questions about these difficulties

How long have these difficulties been present?

- ○ Less than a month
- ○ 1-5 months
- ○ 6-12 months
- ○ Over a year

Do these difficulties upset or distress your child?

- ○ Not at all

○ Only a little

○ Quite a lot

○ A great deal

Do these difficulties interfere with your child's everyday life in the following areas?

	Not at all	Only a little	Quite a lot	A great deal
Home life	○	○	○	○
Friendships	○	○	○	○
Classroom learning	○	○	○	○
Leisure activities	○	○	○	○

Do the difficulties put a burden on you or the family as a whole?

○ Not at all

○ Only a little

○ Quite a lot

○ A great deal

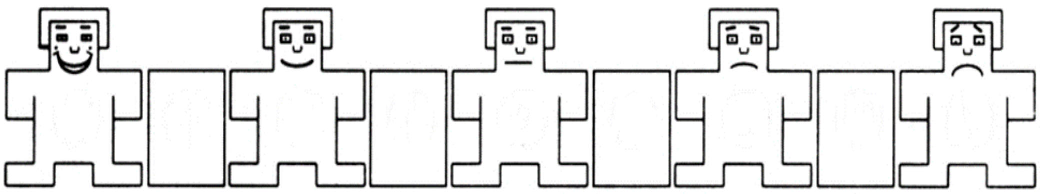
<u>**Open-ended Question:**</u> **When your child shows these difficulties with their behaviour when they [insert context], how do you typically respond?**

Thank you! You have answered the most important questions. We would love to ask you some more. If you would like to continue please let us know. However, if you would prefer to discontinue, please state so now.

◯ I am happy to continue

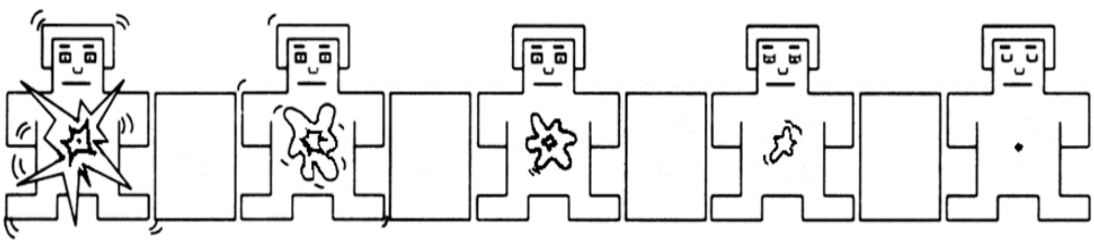
◯ I would like to discontinue

Please indicate how happy or unhappy your child felt in this situation



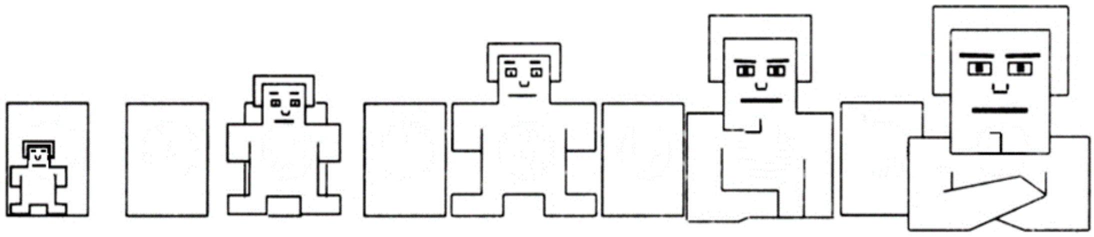
◯ I can’t tell

Please indicate how calm or excited/jittery/nervous your child felt in this situation



◯ I can't tell

Please indicate how big or small your child felt in this situation



◯ I can't tell

Sometimes children show how they feel about a situation through their behaviour and/or in what they say. We would like to know how your child typically responds to the situation you have described. Please indicate how often they show these responses.

If you feel like you can't tell how your child is feeling in this situation, please tell the researcher.

	(Almost) Never	Occasionally	Sometimes	A lot	(Almost) Always
They think that basically the cause must lie	◯	◯	◯	◯	◯

within themselves					
They think they have to accept that this has happened	○	○	○	○	○
They are preoccupied with what they think and feel about what they have experienced	○	○	○	○	○
They think of pleasant things that have nothing to do with it	○	○	○	○	○
They think about a plan of what they can do best	○	○	○	○	○
They look for the positive	○	○	○	○	○

sides to the matter					
They think other people go through much worse experiences	○	○	○	○	○
They think that what they have experienced is the worst that can happen to a person	○	○	○	○	○
They feel that basically the cause lies with others	○	○	○	○	○

Thank you for telling us about the scenario which has the biggest negative impact on your child's life.

Thinking back to the other scenarios (displayed below):

1. After feeling that he/she is being criticised e.g. when other make negative

comments about him/her, or when others tease or ridicule him/her.

2. As a result of a disappointment, e.g. when they receive a less preferred outcome than they were hoping for, i.e. when their sports team loses, or when they cannot have something they want or cannot continue with a preferred activity.

3. As a result of a perceived failure, in other words when they can't achieve a goal, make errors in their work or can't complete a task to the best of their ability.

4. After feeling that he/she is being treated unfairly, e.g. when something is being shared out and he/she receives less than someone else.

Please rank the below scenarios in terms of the negative impact they have on your child's life. You can do this by dragging and dropping the options into the correct position. Number 1 should be the scenario you have previously described, in other words the scenario you think has the biggest negative impact on your child's life, and number 5 should be the scenario you feel has the least negative impact.

If you do not have an example for the 'other situation' option, please rank this as number 5.

______ Being criticised

______ A disappointment

______ A perceived failure

______ Being treated unfairly

______ Another situation (please describe)

Please answer the following questions regarding the scenario you have selected as number 2 (the second biggest negatively impacting situation).

Overall, how would you rate the difficulties your child has in this situation?

- ◯ No difficulties
- ◯ Yes - minor difficulties
- ◯ Yes - definite difficulties
- ◯ Yes - severe difficulties

Do these difficulties upset or distress your child?

- ◯ Not at all
- ◯ Only a little
- ◯ Quite a lot
- ◯ A great deal

Do the difficulties put a burden on you or the family as a whole?

○ Not at all

○ Only a little

○ Quite a lot

○ A great deal

Please answer the following questions regarding the scenario you have selected as number 3.

Overall, how would you rate the difficulties your child has in this situation?

○ No difficulties

○ Yes - minor difficulties

○ Yes - definite difficulties

○ Yes - severe difficulties

Do these difficulties upset or distress your child?

○ Not at all

○ Only a little

○ Quite a lot

○ A great deal

Do the difficulties put a burden on you or the family as a whole?

○ Not at all

○ Only a little

○ Quite a lot

○ A great deal

Please answer the following questions regarding the scenario you have selected as number 4.

Overall, how would you rate the difficulties your child has in this situation?

○ No difficulties

○ Yes - minor difficulties

○ Yes - definite difficulties

○ Yes - severe difficulties

Do these difficulties upset or distress your child?

○ Not at all

○ Only a little

○ Quite a lot

○ A great deal

Do the difficulties put a burden on you or the family as a whole?

○ Not at all

○ Only a little

○ Quite a lot

○ A great deal

Appendix M. Amended SAM script

We call the below set of figures- SAM, and you will be using these figures to rate how you think your child felt in **the situation(s) you described previously**. SAM shows three different kinds of feelings: Happy vs. Unhappy, Excited vs. Calm, and Dominant vs. Submissive. Each SAM figure varies along each scale.

The first SAM scale is the happy-unhappy scale, which ranges from a smile to a frown. At one extreme of the happy vs. unhappy scale, your child feels happy, pleased, satisfied, contented, hopeful. The other end of the scale is when your child feels completely unhappy, annoyed, unsatisfied, melancholic, despaired, bored. If your child feels completely neutral, neither happy nor unhappy, place a mark over the figure in the middle. If you feel like you can’t tell how your child is feeling in this situation, please tick the box which says ‘I can’t tell’.

We would like you think about the situation that has **the biggest impact on your child’s life-** *[prompt which context this is]* and indicate **how happy or unhappy** they felt in that situation, you can indicate this by placing a mark over the figure which depicts the level of (un)/happiness your child felt. If, in your judgment, your child’s feeling of pleasure or displeasure falls between two of the pictures, then place a mark between the figures. This permits you to make more finely graded ratings of how your child felt.

[Presentation of SAM Valence scale]

The following set of SAM figures illustrate the excited vs. calm dimension. At one extreme of the scale your child feels stimulated, excited, frenzied, jittery, wide-awake, aroused. On the other hand, at the other end of the scale, your child feels completely relaxed, calm, sluggish, dull, sleepy, unaroused. As with the happy-unhappy scale, you can represent intermediate levels by placing a mark over any of the other figures or between the pictures. If your child is not at all excited nor at all calm, place a mark over the figure in the middle of the row.

We would like you to indicate how calm or aroused your child felt in the situation *[prompt]*, you can indicate this by placing a mark over the figure (or between figures) that depicts the level of arousal your child felt.

[Presentation of SAM Arousal scale]

The last scale that you will rate is the dimension of dominant vs submissive. At one end of the scale, your child has feelings characterized as completely controlled, influenced, cared for, awed, submissive, guided. At the other extreme of this scale, your child felt completely controlling, influential, in control, important, dominant, autonomous. Note that when the figure is large, your child feels important and influential, and that it will be very small when your child feels controlled and guided. If your child feels neither in control nor controlled you should make a mark over the middle picture. Remember you can also represent your child's feelings between these endpoints.

We would like you to indicate how dominant or submissive they felt in the situation *[prompt]*, you can indicate this by placing a mark over the figure (or between figures) that depicts the level of dominance your child felt.

[Presentation of SAM Dominance scale]